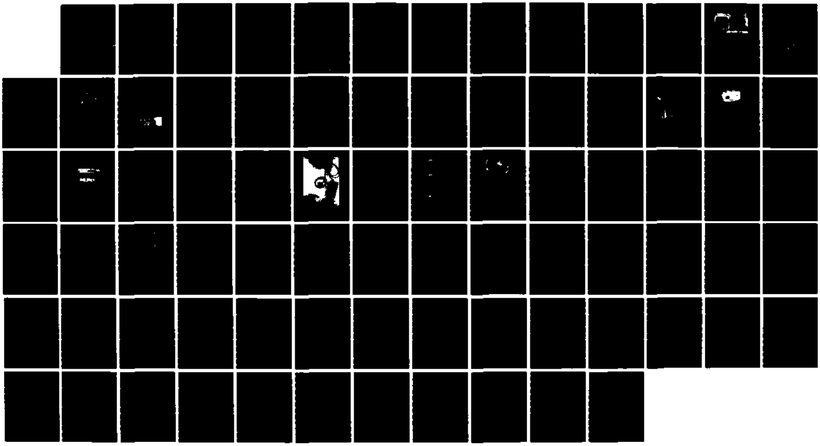
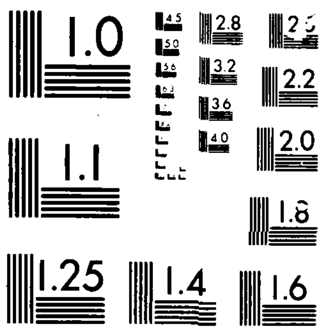
AD-A166 946 A LOW-DATA-RATE VOICE TRANSMISSION SYSTEM (LDRVTS) FOR HF COMMUNICATION(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA G B JOHNSON SEP 85 NOSC/TR-1103 1/1

UNCLASSIFIED F/G 17/2.1 NL






MICROCOP' CHART

TR 1103

TR 1103

# Technical Report 1103
September 1985

# A LOW-DATA-RATE VOICE TRANSMISSION SYSTEM (LDRVTS) FOR HF COMMUNICATION

G. B. Johnson



**Naval Ocean Systems Center**
San Diego, California 92152-5000

**NAVAL OCEAN SYSTEMS CENTER**
**San Diego, California 92152-5000**

**F. M. PESTORIUS, CAPT, USN**
**Commander**

**R. M. HILLYER**
**Technical Director**

## ADMINISTRATIVE INFORMATION

Work for this report assesses speech recognition and synthesis systems as applied to Marine Corps field HF-communication problems.

Released by
C. L. Warner, Acting Head
Systems Design and
Architecture Branch

Under authority of
H. F. Wong, Head
Tactical Systems Division

JA

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A166946

# REPORT DOCUMENTATION PAGE

| | |
|---|---|
| 1a REPORT SECURITY CLASSIFICATION: UNCLASSIFIED | 1b. RESTRICTIVE MARKINGS |
| 2a SECURITY CLASSIFICATION AUTHORITY | 3 DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited. |
| 2b DECLASSIFICATION/DOWNGRADING SCHEDULE | |
| 4 PERFORMING ORGANIZATION REPORT NUMBER(S): NOSC TR 1103 | 5 MONITORING ORGANIZATION REPORT NUMBER(S) |
| 6a NAME OF PERFORMING ORGANIZATION: Naval Ocean Systems Center; 6b OFFICE SYMBOL (if applicable): Code 811 | 7a NAME OF MONITORING ORGANIZATION |
| 6c ADDRESS (City, State and ZIP Code): San Diego, CA 92152-5000 | 7b ADDRESS (City, State and ZIP Code) |
| 8a NAME OF FUNDING/SPONSORING ORGANIZATION: Office of Naval Technology; 8b OFFICE SYMBOL (if applicable): ONT | 9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER |
| 8c ADDRESS (City, State and ZIP Code): 800 North Quincy Street, Arlington, VA 22217 | 10 SOURCE OF FUNDING NUMBERS |

| PROGRAM ELEMENT NO | PROJECT NO | TASK NO | Agency Accession |
|---|---|---|---|
| 62721N | F21245 | CF21245 | DN888 554 |

11 TITLE (include Security Classification)

A LOW-DATA-RATE VOICE TRANSMISSION SYSTEM (LDRVTS) FOR HF COMMUNICATION

12 PERSONAL AUTHOR(S)

G.B. Johnson

| 13a TYPE OF REPORT | 13b TIME COVERED | 14 DATE OF REPORT (Year, Month, Day) | 15 PAGE COUNT |
|---|---|---|---|
| Final | FROM Oct 1980 TO Sep 1984 | September 1985 | 76 |

16 SUPPLEMENTARY NOTATION

17 COSATI CODES

| FIELD | GROUP | SUB-GROUP |
|---|---|---|
| | | |
| | | |

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

Speech recognition
HF communication
Speech synthesis
Marine Corps field-communication problems

19 ABSTRACT (Continue on reverse if necessary and identify by block number)


This report details the present capabilities of speech recognition and synthesis systems in relation to Marine Corps field HF-communication problems. Work includes the design and testing of a battery-powered, field version of a low-data-rate voice transmission system.




| | |
|---|---|
| 20 DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS | 21 ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED |
| 22a NAME OF RESPONSIBLE INDIVIDUAL: G.B. Johnson | 22b TELEPHONE (include Area Code): (619) 225-6143; 22c OFFICE SYMBOL: Code 811 |

DD FORM 1473, 84 JAN

83 APR EDITION MAY BE USED UNTIL EXHAUSTED
ALL OTHER EDITIONS ARE OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

# EXECUTIVE SUMMARY

## OBJECTIVES

The purpose of this task was to assess the present capabilities of speech recognition and synthesis systems, to study the feasibility of applying them to Marine Corps field HF-communication problems, and to demonstrate a breadboard or test-bed communication system, using speech recognition (SR) and speech synthesis (SS).

## RESULTS

At the end of Phase One, it was concluded that SR systems could be effectively applied to the problems of HF voice communication in the field, when performance increased and when the size, complexity, and power requirement of these systems decreased. Phase Two of the task demonstrated that significant progress has been made toward this application.

When appropriate modulation and coding are used in the LDRVTS, the limiting factor in the communication system is no longer the HF channel, but the performance of the SR system. Compared to the average performance of HF voice communications in the field today, the articulation scores and message rates achieved with the new systems are acceptable, especially when syntax and standard messages are used.

## RECOMMENDATIONS

The present setup for training on the SR systems is complicated and difficult to use since an extended CP/M minicomputer is required. Host processors for both the field and base LDRVTS should be modified to have self-contained, speech-pattern training programs.

The modulation and coding should be modified to more closely match the HF channel requirement. The modulation should be changed to a lower symbol rate, and the coding should be simplified to reduce circuit complexity and power requirement.

Higher-quality programmable SS systems should be considered, such as DIGITALKER or a modified DIGITALKER.

Speech-pattern storage should be improved by using larger, lower-powered CMOS memories.

CONTENTS

CONTENTS (continued)

ILLUSTRATIONS

# INTRODUCTION

## BACKGROUND

### Speech Recognition

The first papers on automatic speech recognition appeared over 30 years ago. Since then, computers have greatly enhanced speech recognition capabilities and applications. Several SR systems are now available, from the $200 ten-word system to the $100,000-plus speaker-independent system. The 100-word speaker-dependent system which costs $2,000 (not including host processor) is applicable to the communication system described in this report.

### Speech Synthesis

Speech synthesis has a broad range of applications, from teaching toys (SPEAK-AND-SPELL) to automobile warning systems. The quality of synthesized speech is also quite varied, with the more complex systems producing very high quality speech. Quality of synthesized speech is related to the information stored in memory for each utterance. Most of the good quality speech synthesizers use read-only-memories (ROMs) preprogrammed with a limited vocabulary by the manufacturer. The VOTRAX speech synthesizer provides relatively low quality speech, but it has the advantages of minimal-memory requirement and the capability to be user-programmed with an unlimited vocabulary. These features make the VOTRAX attractive for use in an experimental communication system requiring a Marine Corps field vocabulary.

### HF Communication Problems

Marine Corps voice communication in the field, over HF, is affected by the following:

1. Power limitation -- battery-powered radios
2. Poor impedance matches--physically limited antennas
3. Poor terrain and ground conductivity, combined with poor antennas, yielding unknown radiation patterns
4. Normal diurnal ionospheric propagation fluctuations
5. Tactical situations which result in skywave-groundwave uncertainty
6. Limited frequency availability and assignment
7. Lack of means to evaluate candidate channel frequencies to select the best frequency for a given path
8. Vulnerability to channel interference from background noise and other users
9. The threat of being located by the enemy through radio direction-finding (RDF) fixes
10. Jamming
11. New requirements for voice encryption which demand higher quality channels than presently used for voice communication

## APPROACH

The approach included two phases. The first phase, completed in 1981, involved

1. Surveying available off-the-shelf SR and SS systems to consider cost, size, published capability, and reliability;
2. Developing a feasible application of the speech systems to HF voice communication in the field;
3. Purchasing one speech recognition system and two candidate SS systems;
4. Designing and building circuits to integrate the speech systems into the RF system;
5. Measuring and demonstrating the performance of the entire integrated system on the bench, using only audio signals at bandwidths normally used in communications.

Details of this phase of the task are given in the following sections and in Appendices A and B.

Because the first phase was so promising, the second phase was begun. The second phase included

1. Designing a battery-powered field version of the system demonstrated in Phase One;
2. Evaluating new SR systems as they became available;
3. Devising a scheme to improve the performance of the SR system in the presence of an ambient noise at 80 dB.

## PHASE ONE: LOW-DATA-RATE VOICE TRANSMISSION SYSTEM (LDRVTS)

### SPEECH RECOGNITION SYSTEM

The Interstate Electronics Corporation (IEC) model 1726 Voice Data Entry System (VDES) was selected because, in 1980, it had the greatest flexibility, and a 600-word vocabulary, along with a follow-on model on a multibus board with a 100-word vocabulary. Through size and power reduction, the follow-on model made the IEC system the most easily adaptable to Marine Corps field use. The IEC VDES cost $26,000 including one user station and a dual-disk drive.

A block diagram of the complete Phase One LDRVTS and the associated test equipment is shown in figure 1.

The VDES, shown in figure 2, consists of a DATA GENERAL Nova 3 computer, a dual floppy-disk drive, a CRT/keyboard terminal, a user input station, and a noise-canceling microphone.

As previously mentioned, the SR system must be trained to recognize each of the utterances made by the operator. Training of the VDES is quite simple. First, the vocabulary is entered into the computer. Then, the VDES displays

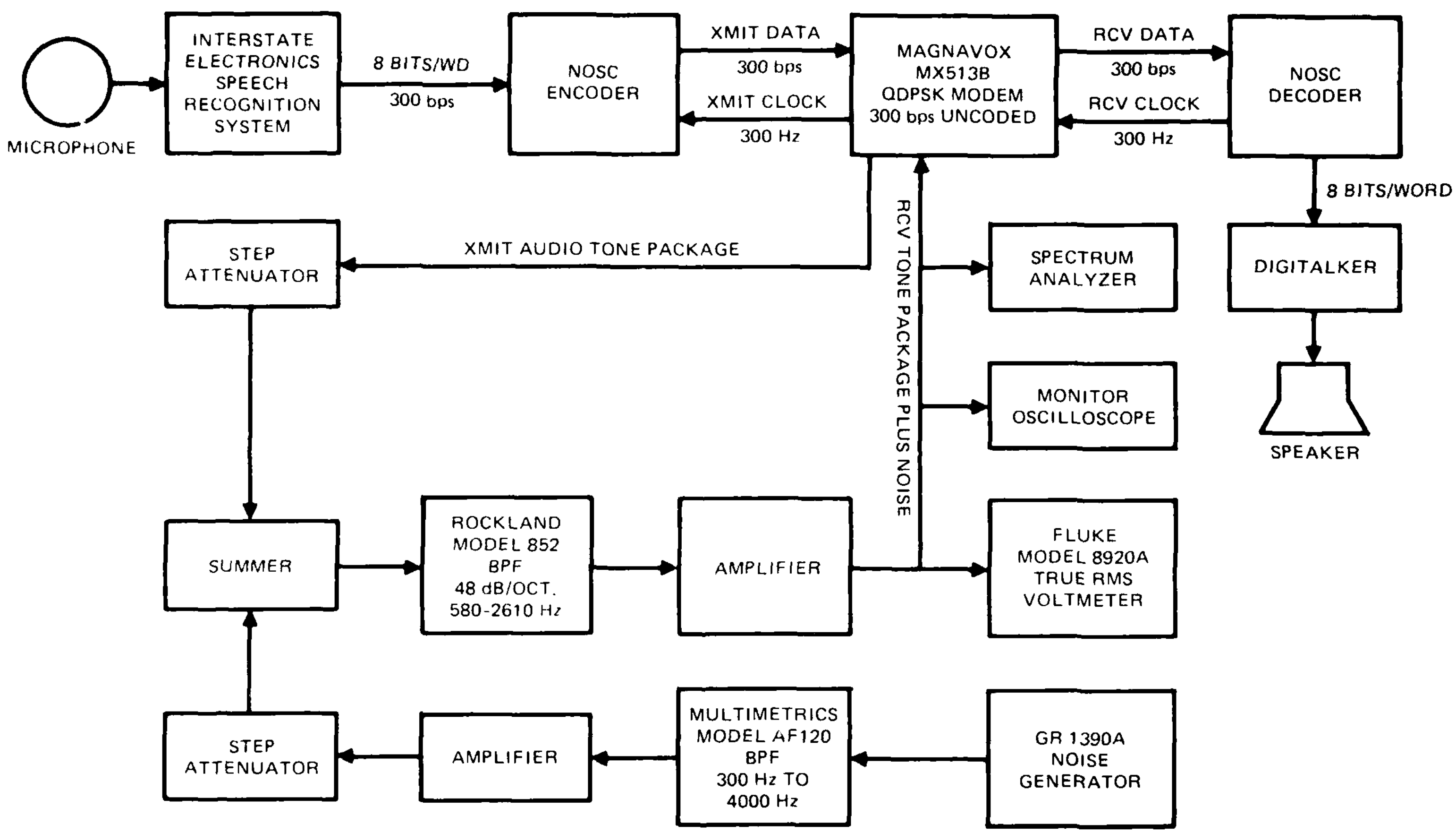



Figure 1. Low-data-rate voice transmission demonstration setup.

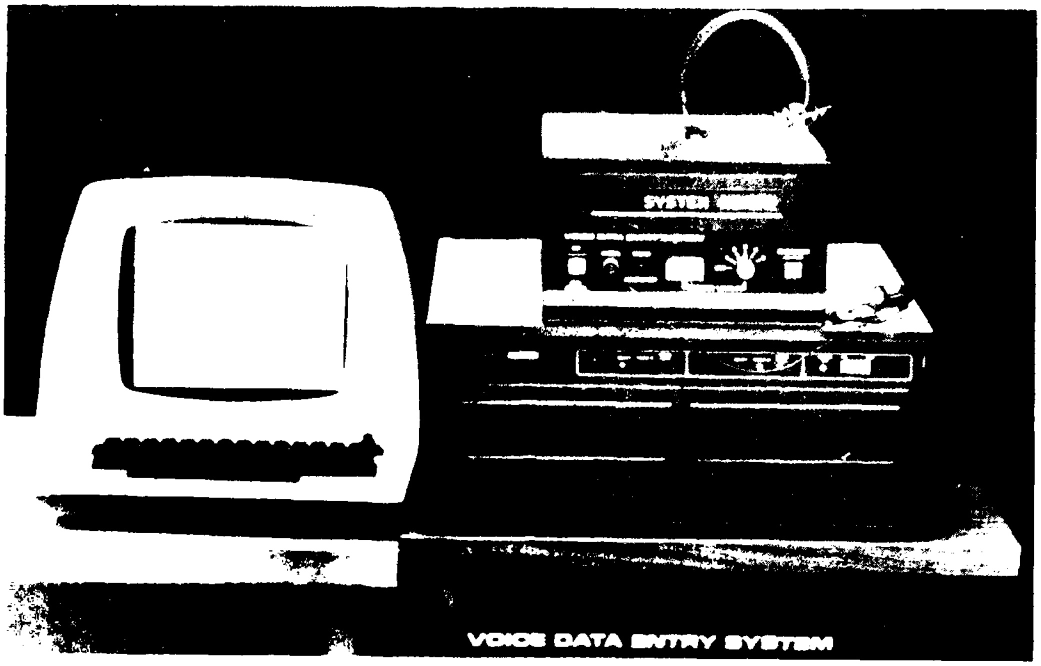



Figure 2. IEC model VDES speech recognition system.

the vocabulary words, one at a time, on the CRT and the user-station readout. As each word appears, the operator says the word into the microphone and the VDES processes the speech signal to develop a pattern of digital data (nominally, 240 bits) for each word in the vocabulary. The initial training series involves three consecutive passes through the entire vocabulary. During the second and third passes, the stored digital pattern is averaged with the recognized speech pattern and replaced in memory with the new, averaged pattern. After the initial three-pass training sequence, an operator should perform four to seven more update training passes at dfferent times of the day, in order to obtain maximum recognition performance from the VDES. The averaged digital pattern for each word in the vocabulary for a speaker must be stored on a floppy disk after each training session. This digital voice-pattern set must be entered into the VDES from the disk (or any other digital-data storage device) before an operator can use the VDES in its voice-recognition mode.

The VDES can be programmed to perform several tasks in response to recognition of vocabulary words, but in Phase One, the VDES response was limited to displaying the recognized word on the CRT and on the user-station readout, and to generating an 8-bit serial code unique to the recognized word.

**RF COMMUNICATION PROBLEM**

Poor signal-to-noise ratio (SNR) is a condition resulting from several problems combined to degrade or destroy voice communication over HF. This SNR condition was selected for speech system application.

Most off-the-shelf SR systems are speaker-dependent. Anyone who operates an SR system must first teach the system to recognize each of the words or phrases. The digital data comprising the operator's speech pattern for each utterance must be loaded into the SR system. The limited vocabulary that can be used with an SR system has the benefit that each utterance in the vocabulary can be uniquely described by an n-bit code, where $2^n$ is the total number of utterances in the vocabulary. The SR systems operate at a maximum rate of approximately 2.5 recognitions per second. Hence, the maximum output-information rate is approximately 20 bits per second (8 bits per utterance). An HF communication system can easily be designed to pass 20 bps when conditions have deteriorated well beyond usability with normal voice or data communication.

## ENCODER

As already mentioned, the maximum information rate from the VDES is approximately 20 bps when the vocabulary consists of approximately 250 words. The function of the encoder (see figure 3) is to take the 8 bits related to a recognized word and stretch it out in time, such that the resulting digital sequence can be transmitted over a very poor channel with a 15 percent loss of bits, while still permitting recovery of the correct 8-bit code upon reception. The word-error rate (WER) or false-alarm rate is approximately $1 \times 10^{-3}$.

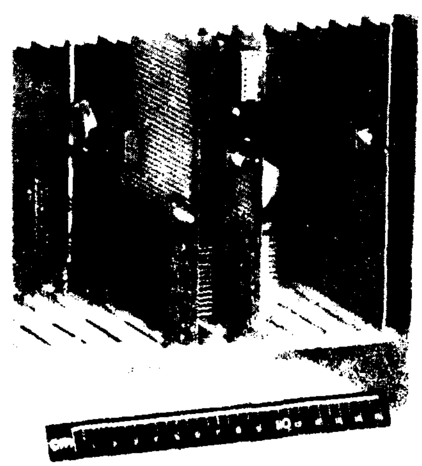


Figure 3 Encoder

The 8-bit code generated by the first recognized word in a message causes the encoder to generate a 128-bit start code, followed by a 128-bit code unique to the 8-bit code from the VDES. The encoder-output data rate is 300 bps. After the transmission of the 128-bit start code and the 128-bit code sequence that follows it, either (a) 128 bits of reversals or (b) another 128-bit sequence relating to the second utterance is transmitted. If the encoder receives no 8-bit code from the VDES for a period of approximately 3-4 seconds, the encoder interprets an end-of-message and sends only reversals. The first 8-bit code from the VDES following an end-of-message causes the encoder to again send a start code, as just described.

The 128-bit digital sequences used are partials of 255-bit maximal length pseudorandom sequences with powerful autocorrelation functions.

## MODULATION AND DEMODULATION

The encoder-output data rate is 300 bps. There are several modulation schemes which permit transmission of this data rate within a band normally associated with HF radios: 0.3 to 3.0 kHz. The modem selected in this task is the MAGNAVOX model MX513B, shown in figure 4. The tone package generated by this modem consists of an unmodulated doppler tone at 605 Hz and 16 quad-differentially-phase-shifted (QDPSK) tones separated by 110 Hz and ranging from 905 Hz to 2555 Hz. The baud rate is 75 symbols per second, providing a maximum internal data rate of 2400 bps. Figure 5 is the spectrum of the MX513B tone package. Lower data rates are obtained within the modem through the use of inband diversity.

As described, the MX513B modulator section accepts a digital input sequence at 300 bps and generates an audio frequency package of 17 tones. This tone package is normally passed to an HF transmitter. The demodulator section of the MX513B normally accepts the 17-tone audio package from an HF receiver and converts it to a digital data sequence at 300 bps. In normal operation, the frequency correction capabilities of the modem are used, but frequency correction was off in this task, for reasons which will be explained later.

## DECODER

The 300-bps data stream from the modem is passed to the decoder, shown in figure 6. The decoder continually searches the incoming data stream for the 128-bit start code. When the start code is recognized, the decoder converts every 128-bit sequence following it to the original 8 bits that uniquely describe the utterance recognized by the SR system. A 128-bit series of reversals is interpreted as a pause, and eight consecutive reversal patterns are interpreted as an end-of-message, causing the decoder to revert to a search for a start code.

The decoded 8 bits are translated by the decoder to digital signals which cause the speech synthesizer to "speak" the received word.

## SPEECH SYNTHESIZER

The VOTRAX SS system was selected because it was the simplest, used the least power, used the least memory per word, and could be programmed by the user to generate virtually an unlimited vocabulary. The only drawbacks to the

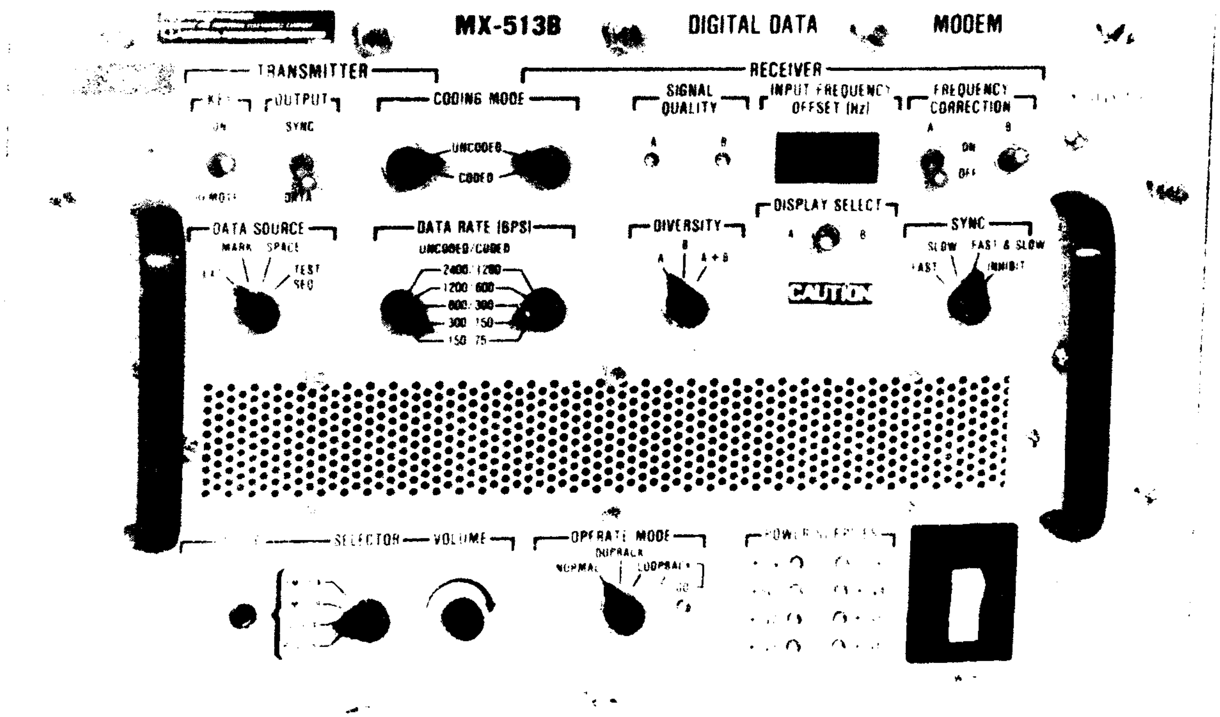



Figure 4. Magnavox model MX513B modem.

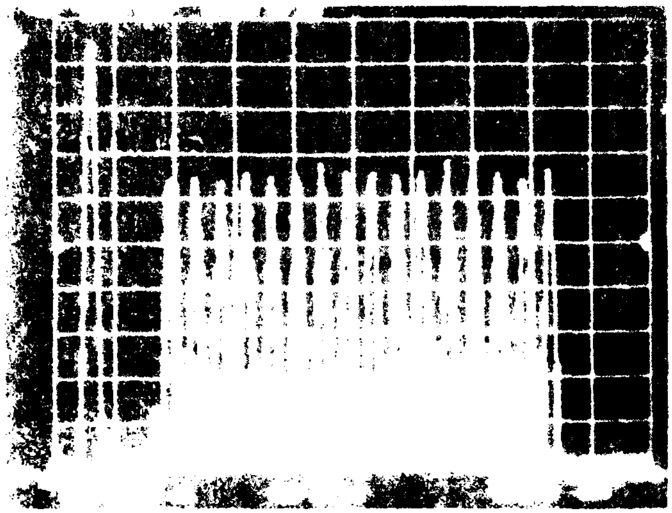


Figure 5. Spectrum of the MX513B tone package. Scale: 2 dB/div., 250 Hz/div. from 500 Hz to 3000 Hz. Sweep and video bandwidths: 30 Hz. Sweep time: 50 sec.

Figure 6. Decoder.

VOTRAX are outlined in the next section of this report. A second speech synthesizer, National Semiconductor's "DIGITALKER," was obtained for short demonstrations before untrained listeners. The DIGITALKER had excellent speech quality, but it had a vocabulary of only approximately 130 words, few of which apply to Marine Corps use.

## PHASE ONE: SYSTEM PERFORMANCE

### SPEECH RECOGNITION

In preliminary laboratory tests with four operators and the 254-word Marine Corps vocabulary (see Appendix C) configured as a single node, the IEC VDES provided a word recognition rate of approximately 91 percent. In this test series, the word list was repeated a total of four times by each operator.

Tests conducted using smaller vocabulary nodes (phonetic alphabet and numbers from 0 to 9) had results of 99 percent recognition (± 1 percent) on the IEC VDES.

### CODING

The coding scheme used in the LDRVTS (the autocorrelation function of a 128-bit partial of a 255-bit maximal length digital sequence) was tested to verify its theoretical performance by varyng the recognition threshold and the bit-error rate (BER) of the received digital data. The recognition threshold can be varied from a correlation value of 64 to 128. If it is 64, the false alarm rate (FAR) is approximately 100 percent, but if it is 128, the word error rate (WER) is nearly 100 percent (in a 10 percent BER) because no bit errors can be tolerated in the 128-bit word. A recognition threshold of 96 provides a WER (and FAR) as a function of BER that is shown in figure 7, if the bit errors are independent. With a recognition threshold of 96, 25 percent of the bits in a 128-bit word must be in error before the word is missed, or a false alarm occurs, or an incorrect word is recognized. The bit-error distribution in white noise depends upon the modulation used, but a normal distribution is a very good estimate when the BER is applied to a word length of 128 bits.

### MODEM

The performance of the MX513B modem in additive white gaussian noise at 300 bps is shown in figure 8. A curve is shown for the normal HF band of 0.3 to 3 kHz, and for the narrower band of the signal only, 0.58 to 2.61 kHz. The MX513B performance curve does not include the effects of frequency offset between transmitter and receiver, or of frame-transition synchronization error. In negative signal-to-noise ratio conditions, the frequency correction capability of the MX513B actually degrades performance. No frequency correction was used in the demonstration.

Figure 9 combines the curve from figure 7 with one of the curves from figure 8 to show the theoretical relationship between WER and SNR, using the MX513B and the "8/128" code. The curve is moved 1 dB to the left to show the relationship of WER and SNR in the normal 0.3 to 3.0 kHz band.

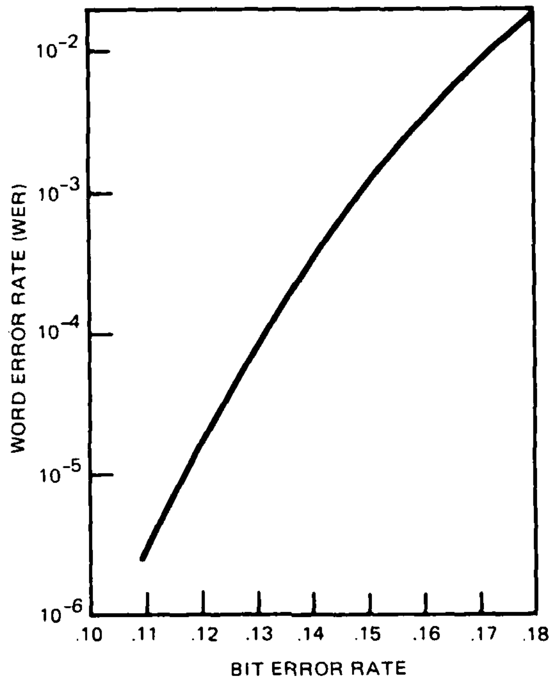



Figure 7. Relationship of WER to BER with the recognition threshold set at 96.

**SPEECH SYNTHESIS**

The LDRVTS can operate with two different speech synthesizers (the VOTRAX and the DIGITALKER). The VOTRAX is the simplest available, and it requires the fewest bits per word (an average of 51). The speech quality is acceptable. However, reactions to demonstrations of the VOTRAX have generally been negative, primarily due to its computerlike quality. It is not immediately intelligible, but a listener can learn to understand it reliably after several repetitions. The VOTRAX can be programmed through the use of its 64 phonemes (6 bits) and 4 pitch levels (2 bits) to generate words from an unlimited vocabulary. The 254-word Marine Corps vocabulary, given in Appendix C, was programmed for the VOTRAX on a single 2716 (2K byte) ROM.

DIGITALKER generates a very high quality speech and requires only a moderate vocabulary ROM (approximately 910 bits per word) and a simple circuit to implement it. Its weaknesses are its higher power requirement and its limited vocabulary, which must be obtained from the manufacturer in ROMs. The vocabulary of the present DIGITALKER, 130 words, is quite suitable for demonstration purposes, but not usable for Marine Corps field communications. Reactions to demonstrations of the DIGITALKER have been very positive.

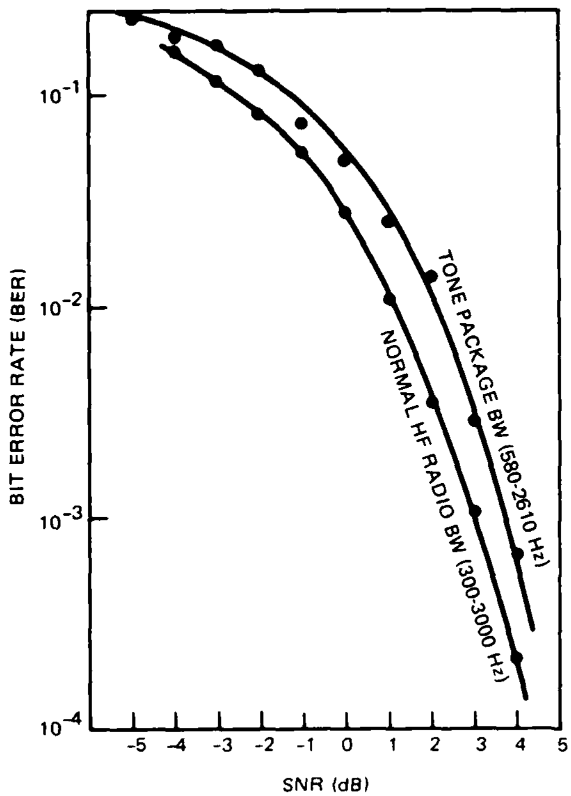



Figure 8. Performance of MX513B modem in white gaussian noise.

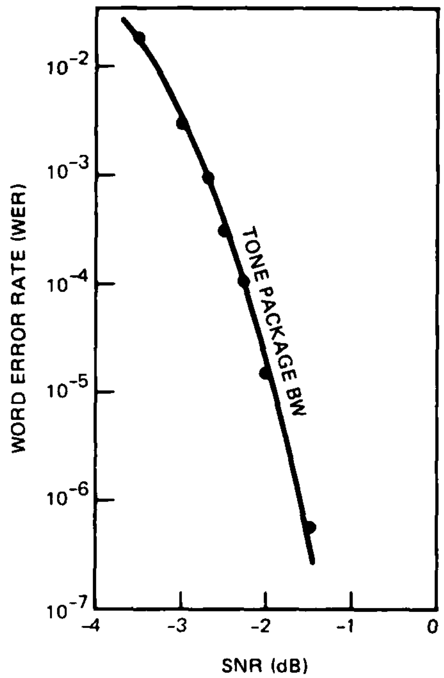



Figure 9. Relationship of WER to SNR using the MX513B and the maximal length sequence code.

The received message buffer, within the decoder chassis, repeats the last 32 received utterances when initiated by the operator. Received words are repeated in a steady stream at a higher rate than that at which they were received. This higher rate is closer to normal speech than the real-time output of the LDRVTS, which has a word rate limited by the recognition rate of the VDES. If a new message arrives while the buffer is repeating an old message, it immediately stops to accept the new message. Reaction to demonstrations of the buffer have been very positive.

**COMPARISON OF PHASE ONE LDRVTS PERFORMANCE WITH CURRENT SYSTEM PERFORMANCE**

For comparison purposes, consider the LDRVTS as three basic components:

1. Speech recognition and consequent generation of 1 byte of data per recognized utterance at the transmit site;
2. Encoding, transmission, reception, and decoding at the receive site to retrieve the byte of data relating to the recognized utterance;
3. Reconversion of the transmitted byte of data to speech (or printout) at the receive site.

Current unencrypted (clear) HF voice communication can be described in a parallel manner as follows:

1. An utterance into a microphone generates an audio frequency signal which is fed to a simple speech-processing circuit within the transmitter;
2. Transmission and reception of the audio-bandwidth signal over the HF channel;
3. Reconversion of the HF signal down to the audio signal, and speech reproduction via a headset or loudspeaker at the receive site.

Use of message formats in current Marine Corps HF field communication suggests that most of the information transmitted over voice radio is contained in the transmitted word, and not in speaker recognition or voice modulation due to the speaker's emotional state.

Articulation Score (AS), the term used to describe speech intelligibility over a channel, is the percentage of words correctly understood when transmitted over a channel being tested. The AS is obtained using standard lists of phonetically balanced words, trained talkers, and trained listeners. AS is used in this report to compare the LDRVTS performance with that of current HF voice communication systems, AM and SSB, in white gaussian noise.

Figure 10 shows a curve, labeled AM, which describes the relationship of AS to SNR in white gaussian noise for an AM transmission with an IF bandwidth of 8 kHz and an audio band of 0.3 to 3.5 kHz. In the same figure, the curve labeled SSB shows the relationship of AS to SNR in white gaussian noise for an SSB transmission with an IF bandwidth of 2.7 kHz and an audio band of from 0.3 to 3.0 kHz. According to these curves, the minimum acceptable performance, (an AS of 78) requires an SNR of 22 dB on an AM transmission channel and 8.5 dB on an SSB transmission channel.

To simplify performance comparison between the current HF voice communication system and the LDRVTSs, assume that of the three basic components of the current system, items 1 and 3 are perfect; item 2 is the only source of degradation; and within item 2, only white gaussian noise exists to degrade performance.

Assume that in the LDRVTS, the same SNR condition exists that degrades item 2 in the current system, and that item 1 in the LDRVTS is not perfect, but has an AS which ranges from 98 (in an office/lab background) to 80 (in the field). The LDRVTS demonstrated a WER of $10^{-3}$ in an SNR of -3.5 dB in the normal HF band (see figure 9). At all SNR values above -3.5 dB, the AS achieved by the speech recognition system, either in the lab (98) or in the field (80), remains constant through the channel. In other words, over all HF channels with white gaussian noise, the LDRVTS intelligibility is constant at the initial value, ranging from 98 to 80, when the SNR is -3.5 or higher. This constant quality is shown in the two curves labeled LAB and FIELD in figure 10.

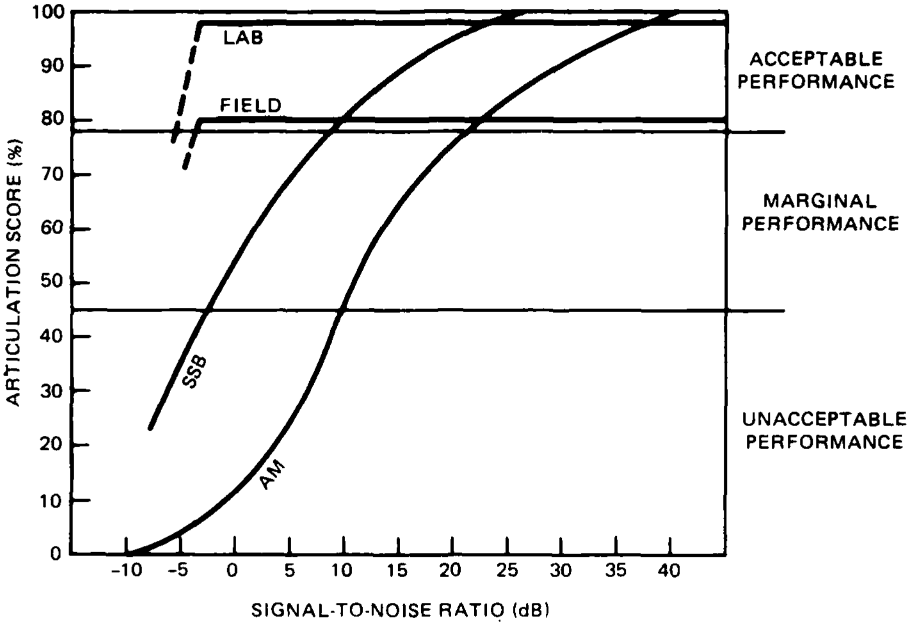



*Figure 10. Performance of current voice communication systems and projected performance of a low-data-rate voice system. (AM and SSB curves are taken from ESD-TR-75-013.)*

Comparing the two LDRVTS curves in figure 10 with the AM curve and the SSB curve, we see that in identical noise conditions, the LDRVTS intelligibility is superior to the SSB intelligibility at all values of SNR below 10 dB for the field and 22.5 dB for the lab. These results include only the effects of white gaussian noise in the channel. There are other channel conditions which degrade performance (e.g., multipath and other users) but these factors are beyond the scope of this task.

Moving on to item 3, reconversion and reproduction, two aspects of performance must be considered in both the current system and the LDRVTS. The first factor is the intelligibility of the audio signal (speech) from the loudspeaker or headset. Assume that degradation from item 2 is negligible in both systems, and only degradation from the listener's perception of the speech must be considered. The current system uses various talkers with different levels of skill and different accents. When a new talker begins, the listeners in the current system must adapt to the speech of the new talkers and the AS must be degraded, at least for awhile. Some talker/listener combinations in the current system will always have degraded AS values. By contrast, in the LDRVTS, the "talker" heard by the listener never changes and has no accent. Therefore, a change of talker at the transmit site cannot degrade the listener's perception of the speech. Every listener becomes trained because the speech heard is always exactly the same, and the vocabulary is limited.

The second consideration in comparing item 3 of the two systems, is that a message-repeat capability is easily included in the LDRVTS--due to the nature of the data actually transmitted (one byte per utterance). If a message is missed due to interruptions or local ambient noise, it can be repeated on site as often as necessary without transmitting a repeat request to the talker. This feature cannot guarantee that the AS will never be degraded because the listener will sometimes miss a word, not be aware of it, and hence not initiate repetition. However, in the vast majority of cases, the LDRVTS eliminates AS degradation due to local noise conditions at the receive site.

## PHASE ONE: CONCLUSIONS

1. At the end of Phase One, available speech recognition systems were too large, too complex, too expensive, and too unreliable to be immediately applied to the most severe Marine Corps HF communication problems.

2. Speech recognition systems will first be applied to those HF communications links requiring only a limited vocabulary. The limited vocabulary may be as high as 2,000 words. The speech recognition system, should be applied to limited vocabulary links well before these systems are able to achieve 99.9 percent recognition rates. The benefits derived from the low information rate more than offset the effect of a 90 percent recognition rate.

3. Speech generation systems available today are small, simple, and inexpensive. Their speech quality is probably superior to what is accepted today on RF and wireline communication links, but they can only be used in limited vocabulary links.

4. When the reliability of speech recognition systems reaches 90 percent in the field, and such a system is incorporated into a low-data-rate voice communication system, the following benefits may be realized:

a. The superior performance of the low-data-rate system in low or negative signal-to-noise ratio channels will permit the operators to either operate in a low-probability-of-intercept mode (LPI) as a normal procedure, or to operate with full power well beyond the point where conditions have prevented communication on conventional communication channels.

b. In a low-data-rate voice transmission system, the message may originate as speech and be regenerated at its destination as speech, hard copy, or visual display. The message may also originate in one language and be regenerated at its destination in another language.

c. Received messages are easily stored electronically for immediate repetition or later review.

d. The present procedure of using compressed and highly formatted messages to ensure communication may be radically altered. Some formatting may be desirable, but speech recognition should remove most of the symbol substitution now required.

e. "Voice" communication will be easily simulated for purposes of deception.

f. Since the speech is transmitted in digital form, encryption will be easy and effective.

5. The performance of the low-data-rate voice transmission system described in this report was achieved through the use of a limited vocabulary, coding, and effective modulation. The same techniques also apply if the message source is a keyboard, rather than a speech recognition system.

## PHASE ONE: RECOMMENDATIONS

1. An experimental field model of the low-data-rate voice transmission system described in this report should be built and tested to better understand the requirements and limitations in the field environment.

2. The state of the art in speech recognition must be closely monitored to permit the earliest application of the technology to Marine Corps field-communication problems.

## PHASE TWO: TASKING

Phase Two of the task included

1. Designing a battery-powered version of the LDRVTS that could operate in the field;
2. Evaluating the performance, size, and power requirements of new SR systems as they become available;
3. Devising a scheme to improve the performance of the SR system in the presence of an ambient noise of 80 dB.

## PHASE TWO: THE LDRVTS

The field model of the LDRVTS was intended to function as a testbed for SR systems, SS systems, host processors, modulation schemes, coding schemes, speech-pattern storage methods, radio interface circuits, and operator interfaces, as well as a means of demonstrating the LDRVTS principle, in the field, with an HF radio.

The design requirements of the field LDRVTS included

1. An off-the-shelf, single-board speech recognition system with a basic vocabulary capability much less than that of the VDES used in Phase One;
2. A host processor for the SR system which was much smaller and less powerful than the NOVA-3 computer used in Phase One;
3. A "realtime" feedback mechanism which permits the operator to know the response of the SR system to his/her speech;
4. The same message-repeat capability as the Phase One system;
5. An HF modem which would fit into the same chassis with the SR system and host processor;
6. The same coding scheme as was used in Phase One;

7. An SS with an authentic Marine Corps vocabulary;
8. Use of an authentic Marine Corps message for testing and demonstrating the system;
9. A means of inserting the speech patterns of various operators into the SR system without the use of a floppy-disk drive, as in Phase One;
10. Self-contained batteries;
11. The capability to key and operate through the PRC-104 HF manpack radio;
12. A rugged case containing everything but the radio.

Along with the listed requirements, two optional but desirable features, a received-message printer and a self-contained speech buffer, were included in the field LDRVTS.

Figure 11 is a photograph of the control panel of the field version of LDRVTS and figure 12 is a photograph of the entire system, excluding the printer and speech buffer which are not included in the present system.

**SPEECH RECOGNITION SYSTEM**

The IEC Model VRM-II speech recognition board is now used in the field LDRVTS. This board has a relatively high power requirement of 1.5 A at 5 Vdc, (due to the use of transistor-transistor logic [TTL] chips) and nominally 200 mA at $\pm$ 12 Vdc. The VRM-II board is capable of operating directly on a vocabulary of 100 utterances, which would be *inadequate for Marine Corps messages* if syntax were not used. However, programmed syntax is easily used with the highly-formatted Marine Corps messages.

Progress made in reducing the power requirement for the SR board is described later in this report.

**HOST PROCESSOR**

The host processor in the LDRVTS consists of an ONSET CPU board and two ONSET memory boards. The host is mounted on both sides of a standard multibus board. The ONSET boards are totally complementary metal-oxide semiconductor (CMOS) technology, based upon the NATIONAL SEMICONDUCTOR NSC800 microprocessor family, so the host power requirement is less than 100 mA at 5Vdc. The CPU clock crystal is presently 4.9152 MHz and this can be raised to 8.000 MHz, for quicker response of the entire SR system.

**FEEDBACK**

A 16-character LCD display, PCIM Model 201, is mounted on the front panel of the LDRVTS to display the words as they are recognized by the SR system. A "WHAT?" is displayed if an utterance is not recognized and all other recognized or misrecognized utterances are displayed, permitting the operator to repeat words when recognition errors occur.

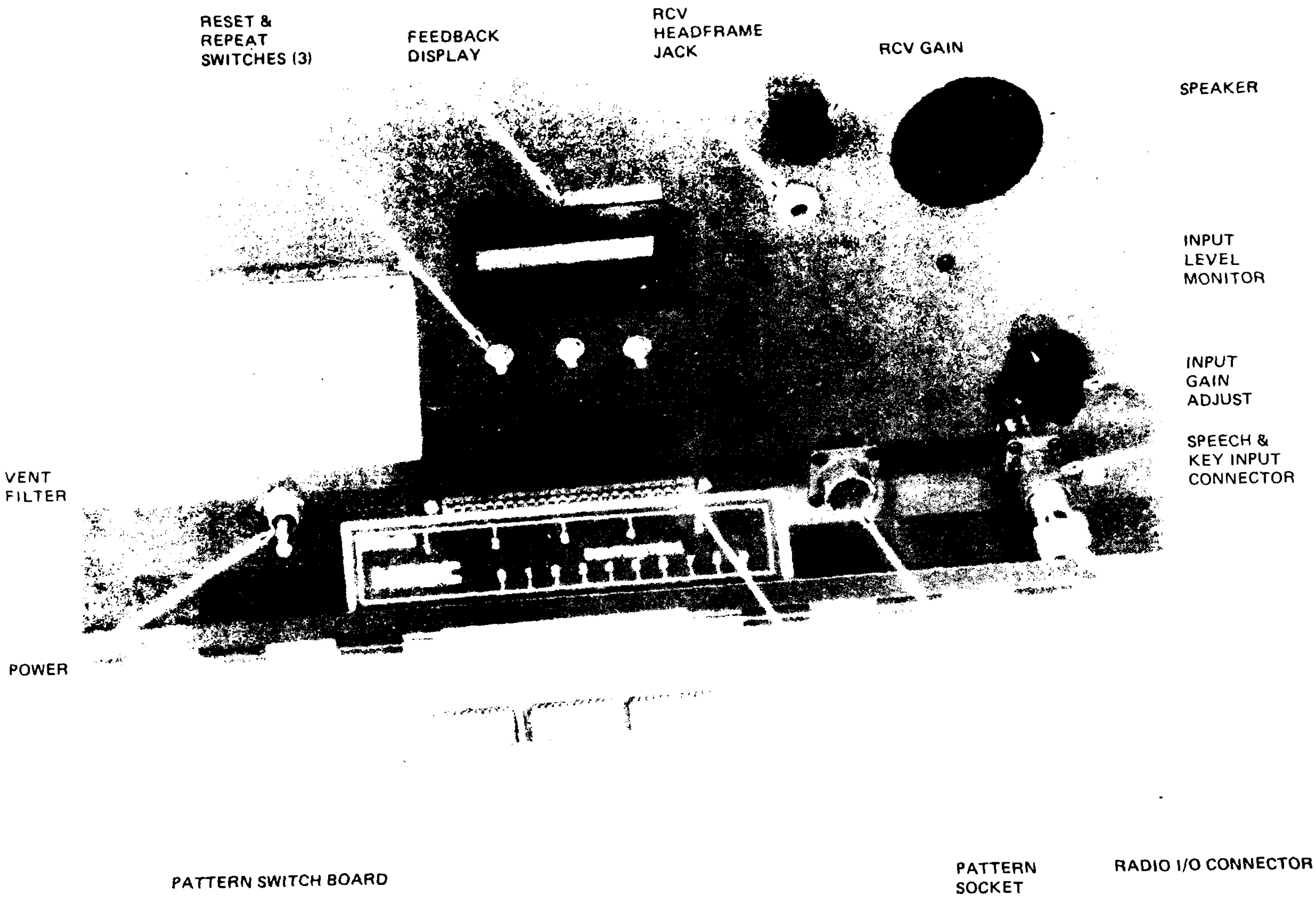



Figure 11. Control panel of field LDRVTS.

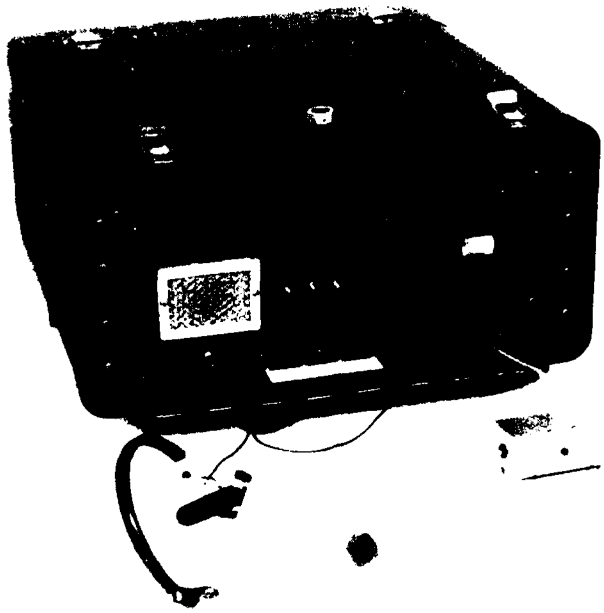


Figure 12. Field model, LDVRTS (excluding printer and speech buffer).

MODEM

The modem is based upon the CMOS 14412 chips, with two of these chips operating in parallel at 150 bps for a total data rate of 300 bps. The block diagram of the modem circuit is shown in figure 13. The modem performance curve (in white noise) is shown in figure 14.

CERMATEK active bandpass filters and phase-lock loops provide a dynamic range of greater than 20 dB.

The transmit clock is derived from an onboard crystal, but the receive clock is based upon the output of a synchronizing circuit which tracks the symbol transitions in each of the tone pairs. Synchronization is adequate for a clock error of approximately 0.5 Hz.

The frequency-shift keying (FSK) tone pairs are 2025/2225 Hz and 1070/1270 Hz with each tone pair carrying alternating bits in the transmitted sequence. Although it is acceptable for demonstration and test purposes, this modem is not optimal for HF communication. The symbol rate of 150 per second is marginally acceptable.

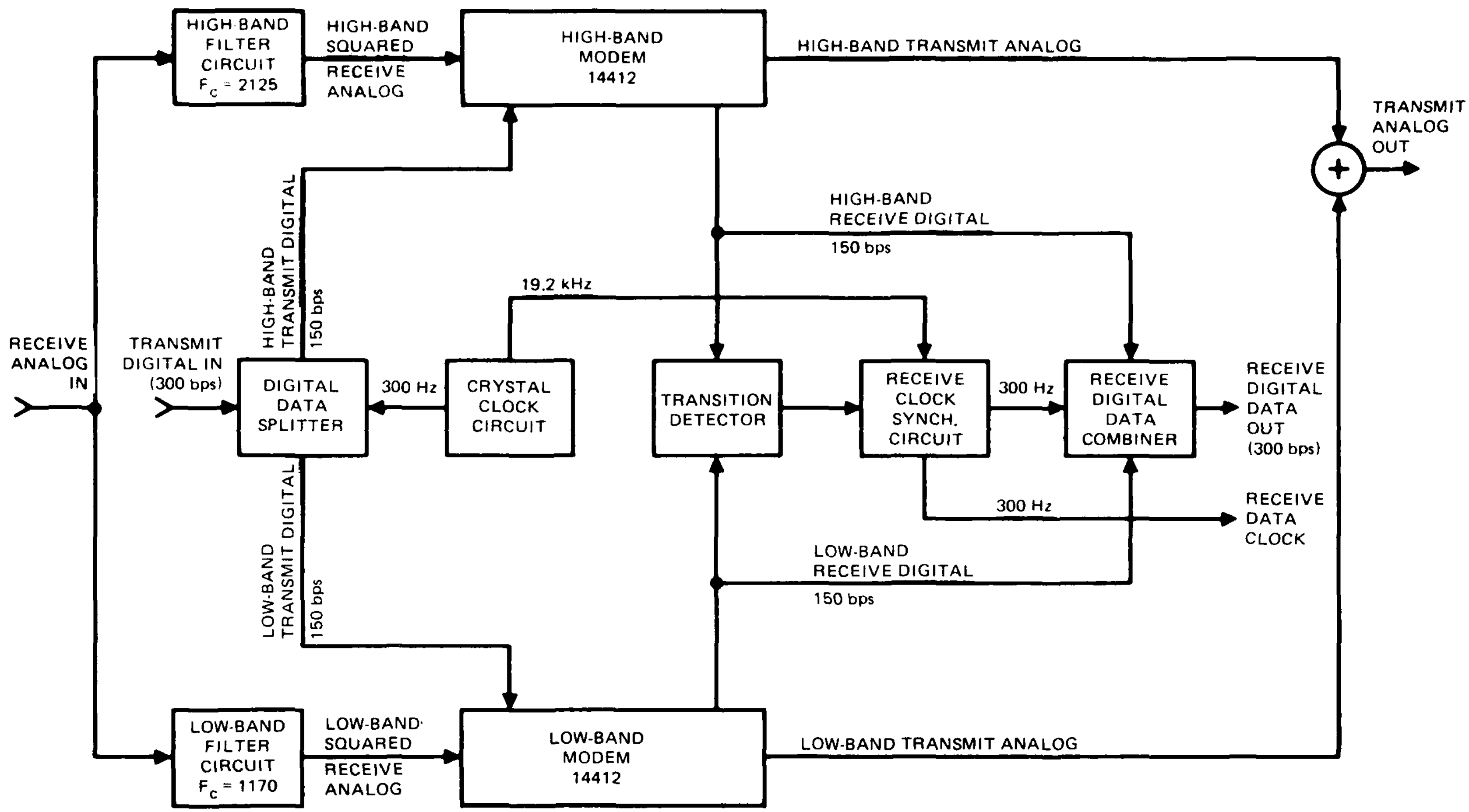



Figure 13. Modem circuit.

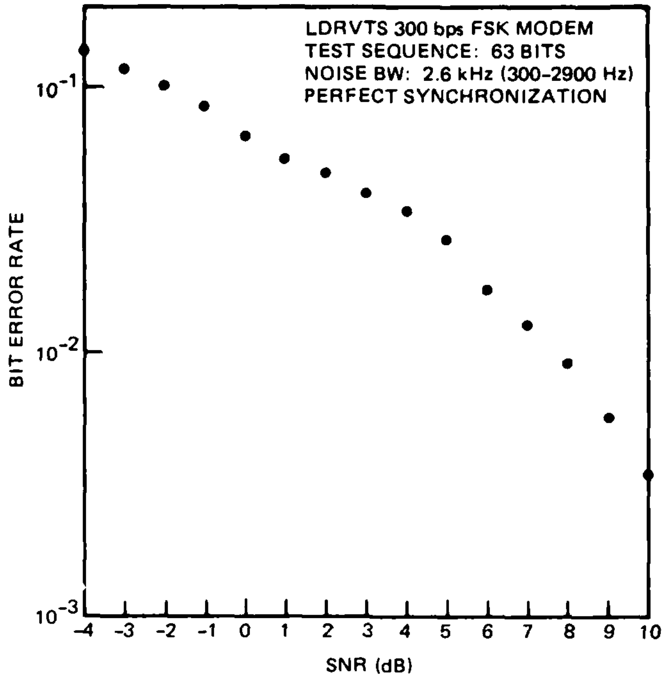



Figure 14. LDRVTS modem performance curve.

## CODING

The same coding used in Phase One is presently used in the field LDRVTS. This is an interim scheme because the coding is probably too powerful for this application. Also, the set of correlator chips now used take too much power (over 400 mA at 5 Vdc).

## VOCABULARY AND TEST MESSAGE

The message used for testing and demonstrating the field version of the LDRVTS is a joint tactical-air-support request, which has a vocabulary of 176 utterances, including phonetic alphabet and numbers. The largest node in the syntax program is approximately 40 utterances, which the VRM-II easily handles. Nodes are loaded into the board from the host processor between the utterances. Appendix A contains the complete vocabulary for the joint tactical-air-support request, including syntax nodes and keywords for the nodes.

## SPEECH SYNTHESIZER

The VOTRAX SS is used in the field LDRVTS. While this SS does not sound quite like human speech, it has certain advantages: it is easily programmed with the required vocabulary; it requires the minimum memory for the vocabulary; and it requires minimum power, since it is CMOS. A production version of the field LDRVTS would use a higher quality SS system with memories that would be custom programmed with the appropriate Marine Corps vocabulary.

## SPEECH-PATTERN STORAGE

Figure 15 is a photograph of the speech-pattern storage card used in the field LDRVTS. The card contains three 24-pin sockets capable of holding three 2732 erasable programmable read-only memories (EPROMS) with a total capacity of 12 kilobytes of data. The present test-message vocabulary uses only approximately 6 kilobytes of this memory.

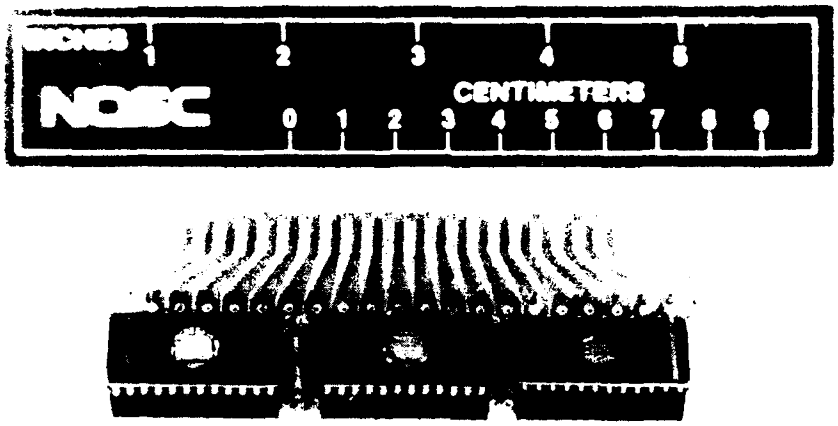



Figure 15. Speech-pattern storage card.

To load the speech patterns into the LDRVTS, the card is inserted into the socket on the front panel and the system RESET button is depressed. The card may be removed after the patterns are entered into the system.

The present speech patterns were made as described in Phase One, but with the VRM-II mounted in its regular chassis and connected to an 8-bit microcomputer operating with CP/M. Speech patterns presently being used are over 1-year old.

## BATTERIES

Most of the weight of the present LDRVTS is due to the batteries, which are mounted at the opposite end of the case from the control panel. Six 5-Ah, 8-Vdc batteries are used, configured as follows: two in series for NEG 12 Vdc, two in series for POS 12 Vdc, and two in parallel for POS 5 Vdc. Battery output is passed through the appropriate regulator for each voltage.

The printer, speech buffer, and the required batteries will all be installed in the case lid.

## PROTECTIVE CASE

The case is a standard, aluminum, electronic-equipment case with a built-in 19-inch rack and 3-inch deep storage lids at each end. The case, larger than need be for the field LDRVTS, permits operation while the equipment is either flat on a table or standing upright on the floor.

## PRC-104 COMPATIBILITY

The LDRVTS is operated through the PRC-104 by placing a special interface between the noise-canceling microphone and the SR system input. This interface includes a push-to-talk (PTT) button, that keys the PRC-104. The LDRVTS output is passed to the PRC-104 through the normal handset input.

The field LDRVTS has been operated only in the transmit mode with the PRC-104 HF radio. Figure 16 is a block diagram of the HF demonstration setup. The demonstrations conducted so far have been preliminary tests of the ability of the LDRVTS to interact with the PRC-104, as well as rough confirmations of the predicted performance of the modulation and coding scheme used in the system. Theoretical performance of these schemes is reasonably well known, but the overall operating performance of the LDRVTS is not yet known. Since the LDRVTS is still in the development stage, complete and rigorous tests are not likely to be performed now. Instead, tests and demonstrations are presently conducted to learn the strengths and weaknesses of the evolving design and to give guidance in the direction of the design.

Rigorous tests, which include details of channel conditions, will be conducted when the LDRVTS design is more nearly acceptable to size, power, and performance requirements of the Marines in the field.

# APPRAISAL OF NEW SR SYSTEMS

## IEC MODEL VRC100

IEC has redesigned its VRM2 SR board to include an improved algorithm and a special analog chip that includes all of the filtering and detection functions that previously required several chips on the VRM2 board. This new design is set up on the same multibus board as the older VRM2, but the circuit density is much lower than it was on the VRM2.

The new IEC design does not include a significant improvement in the power requirement over the VRM2, because most of the circuit is still MOS or TTL. IEC provided NAVOCEANSYSCEN with a bare board containing the printed circuit, but no chips. Sockets were placed on the bare board, permitting the insertion of CMOS chips (74HC series) where TTL chips had been. Although the CPU on the board has not yet been replaced with a CMOS chip, the power requirement has been significantly reduced, from 1.5 A to 0.25 A at 5 Vdc.

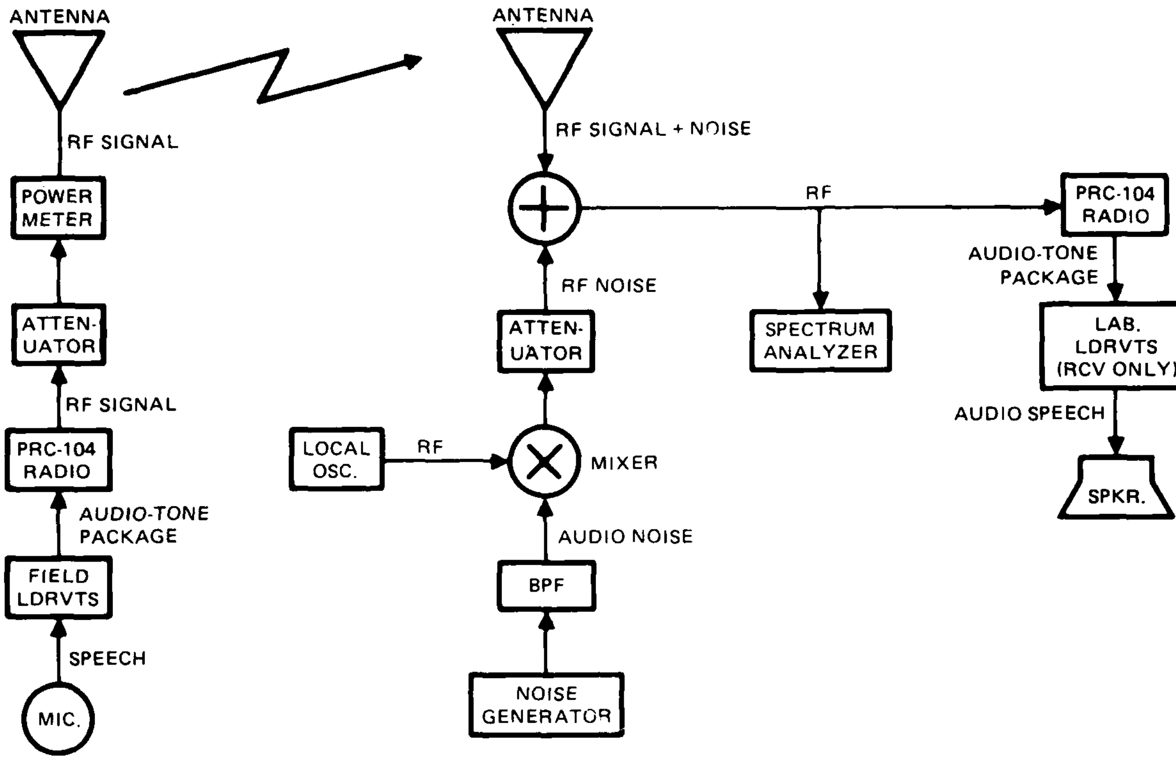



Figure 16. Field LDRVTS demonstration setup.

The modified board has not been fully tested, but preliminary performance assessments are very positive. The 74HC series chips have clock times equivalent to the original 74LS TTL chips, so the board performance should not be degraded at all.

The CMOS SR board has not yet been inserted into the LDRVTS chassis.

**VOTAN MODEL 5000A**

VOTAN has recently demonstrated remarkable performance with its model 5000A, operating with a 10-word vocabulary in the presence of very high (100 dB) ambient noise. The 5000A could not be adapted for use in the LDRVTS, but VOTAN will soon market a single-board version of the 5000A. The 5000A was leased for three months for performance evaluation, with special emphasis given to high ambient noise and a LDRVTS-vocabulary size. The details of the entire evaluation are given in NAVOCEANSYSCEN TD 740, VOTAN V5000 Speech Recognition System Performance Test Report. The performance of the VOTAN 5000A in a quiet background, with a single-node vocabulary of 176 words was excellent, with an articulation score of over 95 percent. However, performance fell off quickly with rising background noise. Small vocabulary performance (23 words) was good at 70 dB, but this fell off severely at 80 dB.

The tested VOTAN was one of the easiest systems to use, with only two training passes required, but it had two drawbacks relating to its application in an LDRVTS. Speech-pattern memory requirement was much higher than that of the IEC systems, and the performance in noise was unacceptable.

A test of the VOTAN system in noise was conducted in the presence of a representative from VOTAN, and the details of the test setup were given to the engineers at VOTAN for duplication. Their only recommendation was to try a newer version of their system.

## IMPROVED NOISE-PERFORMANCE SCHEMES

### VDES PERFORMANCE IN NOISE

A series of tests was made to determine the performance of the IEC VDES in both a quiet background and in fairly high noise. The tests were performed with a maximum vocabulary of 251 words and no syntax. The average articulation score for the large vocabulary was just over 91 percent in a quiet background. The articulation score fell to approximately 80 percent when the background noise (pink) was raised to dBA.

Based upon these tests, it was clear that some means was required to improve the performance of the SR system in high background noise.

The comparison tests were meant to obtain a preliminary assessment of two schemes intended to enhance the performance of the LDRVTS in background noise as high as 80 dB. When the tests were conducted, too many variables existed in the LDRVTS design to permit absolute accuracy. Variables included the SR system used, use of syntax and its effect on performance, and the net effect on LDRVTS performance of unrecognized words.

Although the VDES would not be used in a LDRVTS, it was felt that a scheme which improved its performance in noise might also aid in the LDRVTS SR system.

### EAR COM

Lear Siegler manufactures the EAR COM model 2638A microphone system, based upon an earpiece transducer and a control module, shown in figure 17. Since the transducer fits into the ear and picks up speech primarily through bone conduction, this system has some possibility of improving SR system performance in the presence of high ambient noise, especially when ear-protectors are used.

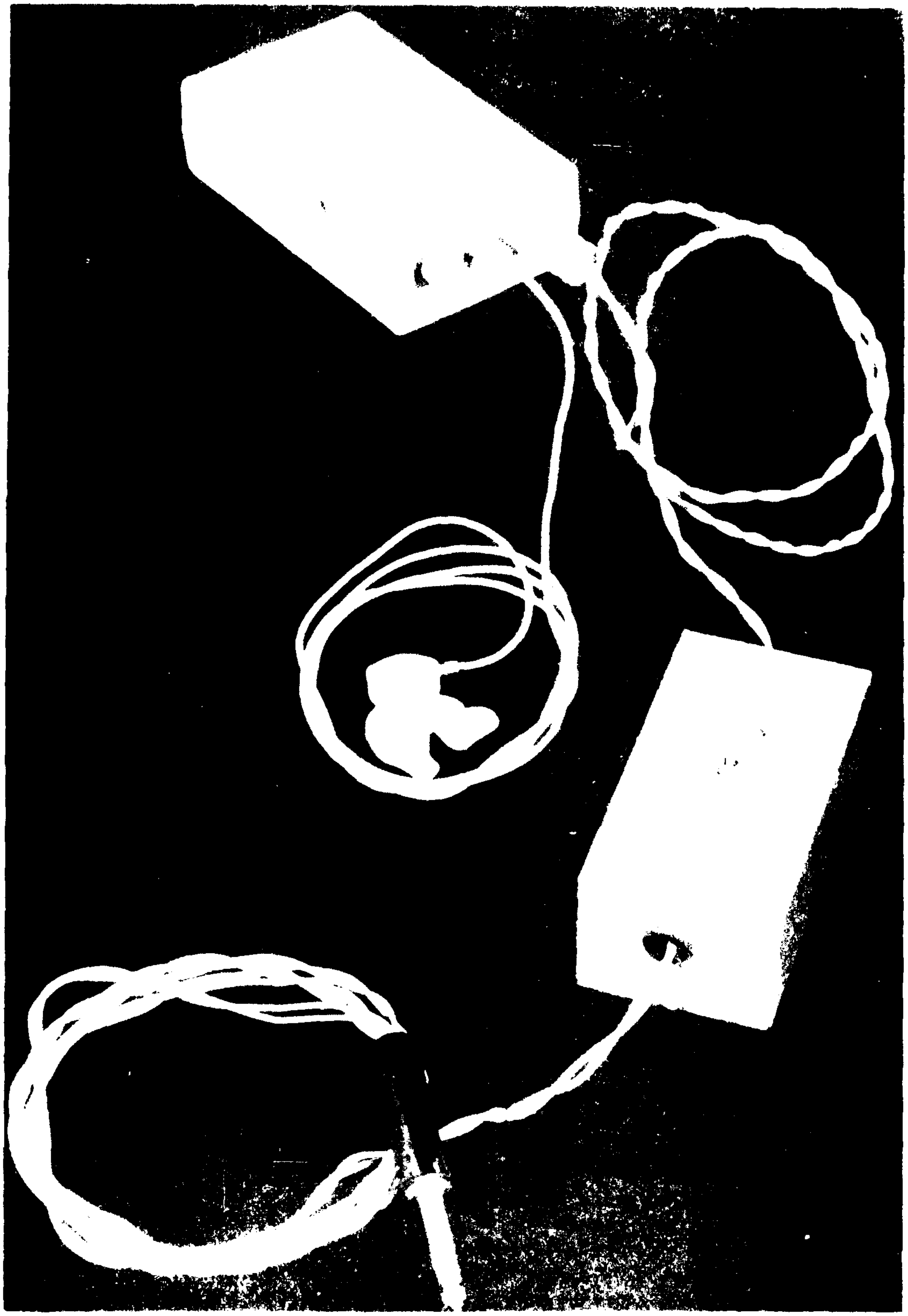


Figure 17. EAR COM 2638A microphone system.

To determine what benefits could be derived from using the EAR COM, four subjects were fitted with custom ear molds into which the transducer was inserted. A series of tests was conducted using the IEC VDES system and 30-dB ear protectors. Performance was unsatisfactory, apparently due to the loss of feedback through the ear protectors. (See figure 18a.) To overcome this loss, the system was modified by amplifying the control-module output and feeding it back to the speaker's other ear through a simple earpiece, as shown in figure 18b. The performance of this system will follow in this report.

## EXTERNAL MICROPHONE AND FEEDBACK

To further explore the benefits of ear protectors and feedback, a SHURE model SM10 noise-canceling microphone, normally used with the VDES, was configured as shown in figures 18c and 19.

## PERFORMANCE COMPARISON TESTS

Appendix A contains the details of the performance comparison tests of the IEC VDES using

1. The standard external microphone
2. External microphone, ear protector, and feedback
3. EAR COM, ear protector, and feedback.

The vocabulary consisted of 170 words from a standard Marine Corps message (joint tactical-air-support request). Thus, the VDES was programmed to operate using syntax. Use of syntax presented special problems in the interpretation of performance scores for the tests, since the misrecognition of a syntax-node keyword in place of a normal word caused the VDES to go to a node in which the next test word uttered might be excluded. The interpretation of the scores was not very important in the evaluation, because the same error-causing mechanism was operating for each of the three schemes being tested. When such a misrecognition occurred, subjects were instructed to speak the keyword of the node their current word was in, then continue the test. The test results were printed out simultaneously, so the analyzer merely counted the first error, and ignored the words and errors that occurred while trying to return to the correct node.

Since the operator had immediate feedback as to what the SR system recognized, and since the LDRVTS application was not seriously penalized by an unrecognized utterance, unrecognized utterances were not counted as errors in this comparison. Scores obtained must not be considered as accurate articulation scores for the VDES, merely as "recognition" scores for purposes of comparison.

The scheme using the external microphone, ear protectors, and feedback provided acceptable performance in an 80-dB background-noise environment. In a quiet environment, this scheme provided a recognition score only 2 percent below that obtained by the external microphone alone. When the 80-dB noise was added, the recognition score dropped by only an additional 1.6 percent, or 3.6 percent below the score obtained by the external microphone alone, in a quiet background.

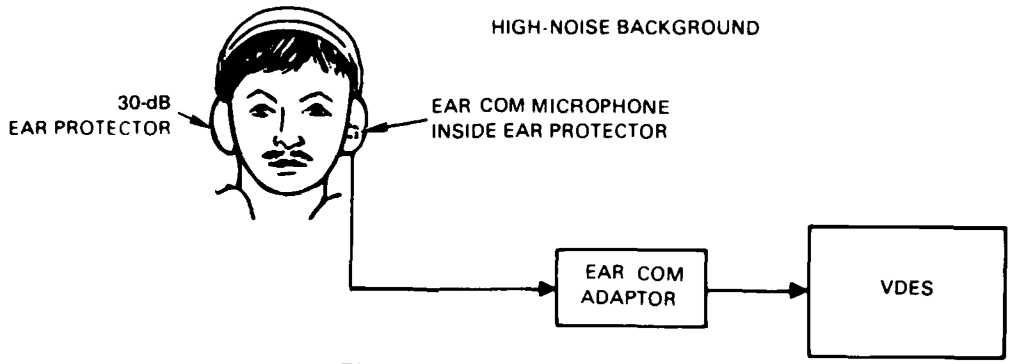



Figure 18a. EAR COM test setup.

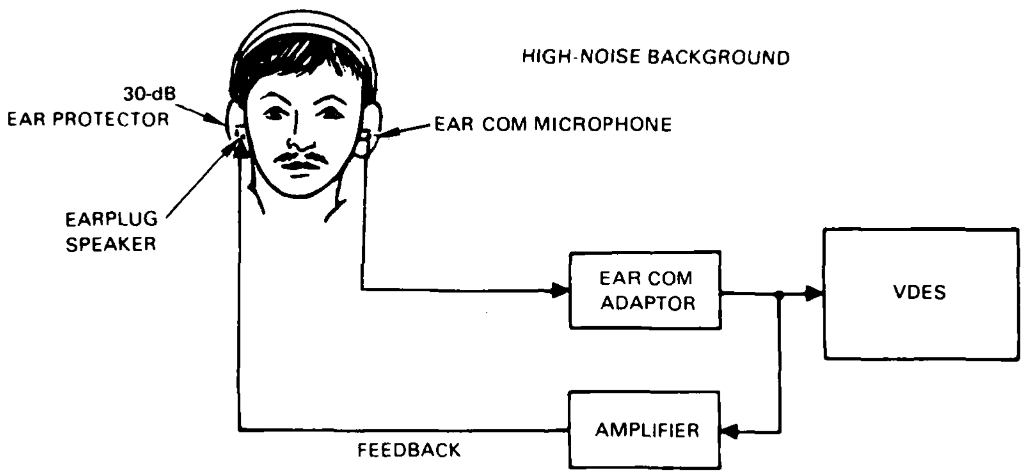



Figure 18b. Improved EAR COM test setup.

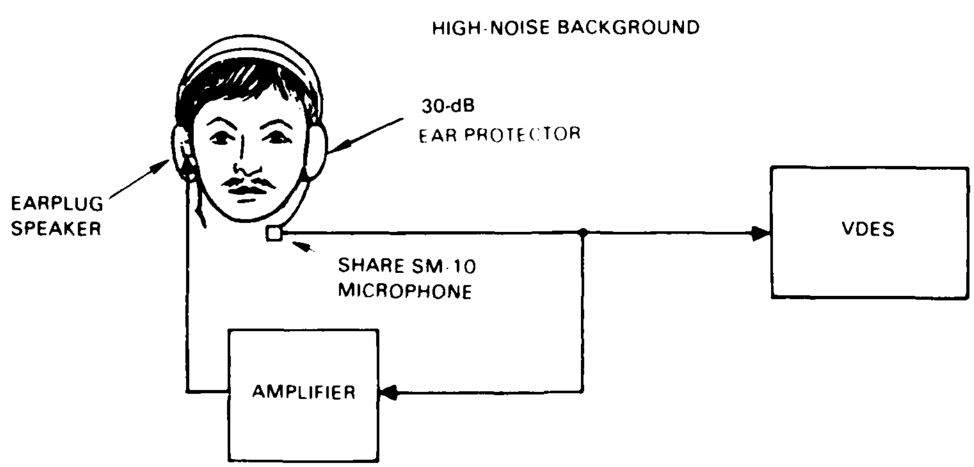



Figure 18c. Feedback system with noise-canceling microphone.

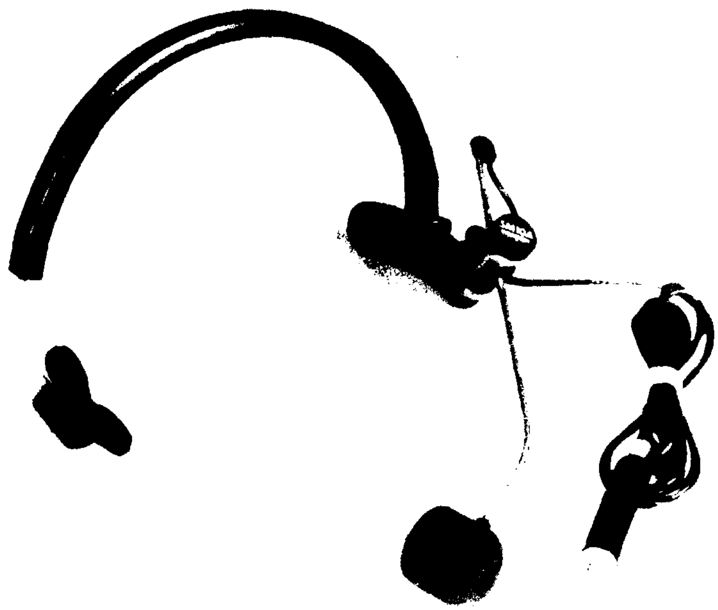


Figure 19. SHURE model SM10 noise-canceling microphone.

The scheme using EAR COM, ear protectors, and feedback also performed adequately in 80-dB noise, but the scores varied over a greater range from subject to subject. The scores obtained with the EAR COM scheme were 3 percent to 10 percent lower in quiet background than the external microphone schemes. The scores held quite steady when the 80-dB noise was turned on. For some subjects, the noise was raised through 90 dB with EAR COM, and scores of 96 percent were obtained. When the noise was raised to 96 dB with EAR COM, the scores decreased to 87 percent.

## PROBLEMS AND NEAR-TERM PLANS

### SR System

The original SR system (IEC VDES) has become obsolete and very inefficient for experimental purposes in LVDRTS development. The IEC multibus-board SR family (VRM2, etc.) appears to be the most promising candidate system for the LDRVTS. Two of these SR systems are now on hand (CMOS and TTL). In the near future, the TTL SR system will be set up with the modems and coding circuits to serve as the base, non-portable LDRVTS. The CMOS system will be installed in the field LDRVTS.

The present setup for training on the SR systems is complicated and difficult to use since an external CP/M minicomputer is required. The host processors for both the field and base LDRVTS will be modified to have self-contained, speech-pattern training programs.

A performance evaluation of the new IEC VRM SR system, as configured in the LDRVTS, will be conducted.

### Radio Interface

Preliminary operation of the LDRVTS with the PRC-104 has uncovered a problem with feedback from the radio to the LDRVTS that makes the entire system inoperable. This is not a difficult problem, but it must be solved before complete two-way demonstrations of the LDRVTS are conducted.

### Operator Interaction

Preliminary tests of the LDRVTS with the PRC-104 have also demonstrated the need to accommodate the radio key line to the LDRVTS operating sequence. The operator has a tendency to release the PTT button too soon after the message is complete. The coding and transmission of the resulting bit stream occurs after the SR system completes its processing, which necessarily follows the utterance. Hence, the radio must be keyed continuously until this bit sequence is transmitted. The LDRVTS circuit must be modified to automatically key the radio through the final bit sequence of a message.

### Accessories

The speech buffer, which is not in the present system, has a built-in clock which is read in the LCD display. Received messages are assigned starting times when they begin, and the entire message and its starting time are stored in the buffer. A total of 1,800 words of received message can be stored and recalled from the speech buffer, and repeated through the built-in VOTRAX SS and a headphone or earpiece. The buffer is controlled through the keyboard to repeat messages either by starting time, or by forward or backward sequences.

Another accessory not in the present system is the LDRVTS printer. Both the speech buffer and the printer have been demonstrated external to the LDRVTS. The printer prints out the received messages as the VOTRAX synthesizes the received-message speech.

## DESIGN DIRECTION OF LDRVTS

At the end of Phase One, it was concluded that SR systems could be effectively applied to the problems of HF voice communication in the field, when performance increased and when the size, complexity, and power requirement of these systems decreased. Phase Two of the task demonstrated that significant progress has been made toward the realization of this application.

It must be recognized that when appropriate modulation and coding are used in the LDRVTS, the limiting factor in the communication system is no longer the HF channel, but the performance of the SR system. Compared to the average performance of HF voice communication in the field today, the articulation scores and message rates achieved with the new systems are acceptable, especially when syntax and standard messages are used.

Marginally acceptable performance of the system (a 90 percent articulation score) has been demonstrated in a noisy background, up to 80 dB. This performance is bound to improve with the application of dedicated and refined circuits.

The multibus boards, containing the SR system and the host processor in the present LDRVTS, represent a great reduction in the size and complexity of a functioning system compared to the VDES used in Phase One. It is possible to condense the two multibus boards used in the SRT/host into one-half board through off-the-shelf chips and multiwire. IEC has recently announced a new chip which replaces most of the remaining analog circuit on its VRM-family SR system board. This will reduce the size of the system even further.

Phase Two demonstrated a significant reduction in the power required for the SR/host compared to earlier versions. This power requirement will decrease further when the MOS microprocessor is replaced with a CMOS microprocessor on the VRM board.

## LONG-TERM PLANS FOR THE FIELD LDRVTS

The modulation and coding will be modified to more closely match the HF channel requirement. The modulation will be changed to a lower symbol rate and the coding will be simplified to reduce circuit complexity and power requirement.

Higher quality, programmable SS systems will be considered, such as DIGITALKER or a modified DIGITALKER.

Refined syntax program will be developed to reduce the effect of misrecognition errors.

Speech-pattern storage will be improved by using larger, lower-powered CMOS memories.

Speech pattern and message relationship will be established and a management system will be set up within the host to accommodate more than one type of message.

When these steps have been accomplished, the smallest feasible chassis will be designed for the system.

## BIBLIOGRAPHY


Fitzgerald, W. J., VOTAN V5000 Speech Recognition System Performance Test Report, NAVOCEANSYSCEN TD 740, August 1984.

Gelfand, S. A., Hearing, Marcel Dekker, Inc., 1981.

Hirsh, I. J., The Measurement of Hearing, McGraw-Hill, 1952.

Kravitz, et al., Communications/Electronics Receiver Performance Degradation Handbook (2nd Edition), ESD-TR-75-013.

Lea, W. A., Trends In Speech Recognition, Prentice-Hall, Inc., 1980.

Poock, G. K., A Longitudinal Study of Computer Voice Recognition and Vocabulary Size, NPS55-81-013, U.S. Naval Postgraduate School, Monterey, CA.

Reddy, D. R., Speech Recognition, Academic Press, 1975.

# APPENDIX A

# VOICE DATA ENTRY SYSTEM (VDES) PERFORMANCE TEST REPORT

GENE GUSMAN
(Student Aid)

JUNE 1983

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

## ABSTRACT

In order to reduce the effect of noise on the IEC Model 1764 VDES performance, various methods of voice entry were tested. The first mode consisted of an external microphone, a feedback earphone, and a noise protective headset. The second method employed the EAR COM microphone, which when placed in the ear, received sound from bone conduction. Again, a feedback earphone and a protective headset were used. Testing was done on five subjects, four males and one female, over a 2-month period. The test message was 138 words.

## INTRODUCTION

The IEC VDES model 1764 (previously shown in figure 2) is an isolated word, automatic speech recognizer. The vocabulary to be recognized is part of the voice program (Appendix B) stored in the host NOVA 3 computer. The maximum usable vocabulary is 650 words. The user trains each word by repeating it, after which it is stored as a template to be referenced later for recognition. Five to ten training passes are recommended by the manufacturer. The vocabulary used was the Marine tactical air request. In hope of reducing errors, syntax was used to limit the vocabulary size to be recognized for any specific utterance.

The purpose of this experiment was to reduce the effect of noise in VDES performance by altering the voice-entry scheme. In the presence of noise, it was found that subjects change their speech patterns, thereby reducing recognition scores. By using a sound-protective headset and a feedback mechanism to allow the subject to hear his voice, it was thought that recognition scores would improve.

Three schemes were used:

1. The SHURE model SM10 professional head-worn microphone (figure 19) is a low-impedance, unidirectional, dynamic microphone.

2. The SHURE model SM10 was used with a sound-protective headset. The signal was taken before entering the VDES and fed back through a HEATHKIT AA-18 amplifier to an earphone worn underneath the headset (figure 18).

3. The EAR COM 2638A system consists of an earpiece transducer and control module (figure 17). The transducer senses vibrations due to bone conduction in the ear. The vibrations are transmitted to the control module which then alters and amplifies the signal. Earmolds were made for four of the subjects out of a soft vinyl material called "Silky Soft," and the transducer was plugged into the channel entrance in the mold. In this case, the signal required attenuation by a HEWLETT-PACKARD 350D attenuator set before entering VDES. After the attenuator, but before entering the VDES, the signal was again phased through the HEATHKIT amplifier for feedback.

The independent variables were as follows:

1. Vocabulary
2. Length of test message

3. Recognition threshold
4. Syntax
5. VDES gain
6. HP attenuation
7. HEATHKIT amplification
8. Noise level
9. Noise direction
10. Elapsed time between training and testing
11. Experience in voice testing
12. Microphone position
13. Fatigue
14. Sex of subject
15. Number of training passes

The following variables were kept constant:

1. Vocabulary - tactical air request
2. Length of test message - 138 words
3. Recognition threshold - 110 (default value)
4. Syntax
5. Noise direction
6. Microphone position (as constant as possible)
7. Number of training passes--7

Recognition Threshold: The default value of 110 was decided upon after the experimenter trained and tested with different levels.

VDES Gain: The VDES gain was adjusted to suit the subject and then kept constant for that particular subject's testing. The levels used for noise testing were varied to maximize performance.

HP Attenuation: This was adjusted for each subject.

HEATHKIT Amplification: This level was adjusted for adequate feedback and kept constant throughout the experiment.

Noise Level: This was varied between 75 and 100 dB. Most of the testing was done using 80 dB.

Noise Direction: Since the SHURE microphone is unidirectional, the noise source was aimed away from it for testing. When aimed at the microphone, the noise interferred so that testing was not possible.

Fatigue: Since fatigue affects performance as test duration increases (Pook and Armstrong, "Effect of Task Duration on Voice Recognition System Performance," 1981) short time intervals were allotted between tests. Usually, no more than three tests (138 words each) were performed in a test session.

Experience in Voice Testing: It was expected that subjects with no prior experience with voice-recognition systems would improve their performance with time.

Position of Microphone: The head-worn microphone was adjusted 1 to 2 inches from the left corner of the mouth of each subject. This position was measured using one or two fingers of the subject as a guide, and repositioned in this way for each test. Since the higher frequencies of the female voice are more directed, the microphone was positioned in front of the corner of the female's mouth rather than at the side.

Syntax: This was used to limit the vocabulary size for each utterance so as to reduce the probability of error. In order for the VDES to recognize a word in a particular subgrouping of the vocabulary (called a node) the subject must have been previously recognized as having spoken the entry name of the node.

Time Between Train and Test: In an earlier study, recognition scores were shown to decrease as the elapsed time between training and testing increased.

Training Phases: The manufacturer recommended using five-to-ten passes. We used seven. The effects of varying the number of training passes were not tested.

Sex of Subject: The difference between male and female performance was not tested.

## PROCEDURE

Five subjects trained the VDES for a 170-word vocabulary with seven training passes in each of two configurations; external microphone and external microphone with feedback. Four of the subjects trained in a third configuration using EAR COM.

After training, the subjects tested VDES with a 138-word test message (Appendix C) as follows:

| SUBJECTS | CONFIGURATION |
|---|---|
| 1,2,3,4,5 | External MIC |
| 1,2,3,4,5 | External MIC with feedback |
| 1,2,3,4,5 | External MIC with feedback and noise |
| 1,2,3,4 | EAR COM |
| 1,2,3,4 | EAR COM with noise |

Subject 5 was female and subjects 1,2,3, and 4 were male.

White background noise from 0-5 kHz (figure A-1) was produced by a WAVETEK model 132 VCG/noise generator; A MULTIMETRICS model AF 120 active filter; and an HP 467A power amplifier.

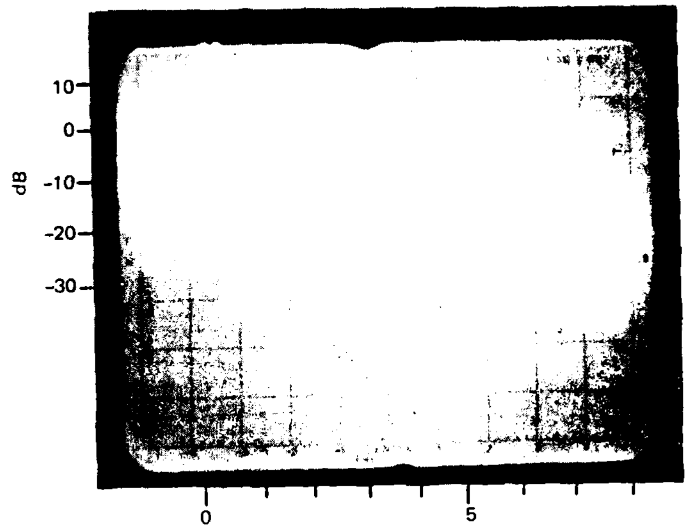



Figure A-1. White background noise.

VDES sometimes left a node because it incorrectly recognized a node entry word. In that case, the subject was instructed to repeat the entry word of the node that he or she was in, and to continue with the word after the one erroneously recognized.

A printout was obtained of the recognition scores for the recognized word and the word with the next-highest score. An analysis of this data might reveal the effect of threshold on recognition, and also might indicate how to better construct the syntax.

## SCORING

The recognition scores were computed as follows:

Score (%) = ( 1 - < Erroneous Recognition/# of words>) *100

Upon repetition of a word, the feedback display unit (FDU) either displayed a recognized word or a "What?". The response "What?" was displayed when the recognition level was below the threshold. Since no incorrect recognition occurred, this was not considered an error unless 10 repetitions were unrecognized.

## RESULTS

The data are presented in tables A-1 through A-6 and figures A-2 through A-6. Table 6 shows the mean and standard deviation for each subject in each test configuration. Figures A-2 through A-6 present graphically the results in table 6.

For the external microphone and feedback configuration, only the test with VDES gain = 2 was graphed, since this was the same gain used in the noise test configuration. A comparison of the two tests with different VDES gain levels, and thus, two uncontrolled variables, would not be conclusive.

Recognition scores ranged from 88 to 99 percent for the external microphone configuration; 88 to 98 percent for the microphone with feedback; and 86 to 97 percent with feedback and 80 dB background noise. The EAR COM scores ranged from 69 to 96 percent and from 79 to 95 percent with noise. EAR COM not only had the widest performance variation with individual subject, but also had the largest variation with individual test by the same subject (as seen by the large standard deviations).

## CONCLUSIONS

The effects of noise were meaningfully reduced using the external microphone, headset, and feedback for background levels up to 80 dB. Performance with the headset and without noise was degraded only 2 percent from the results with the external microphone alone. Performance of the external microphone and headset was degraded only 1.6 percent by the addition of 80-dB background noise.

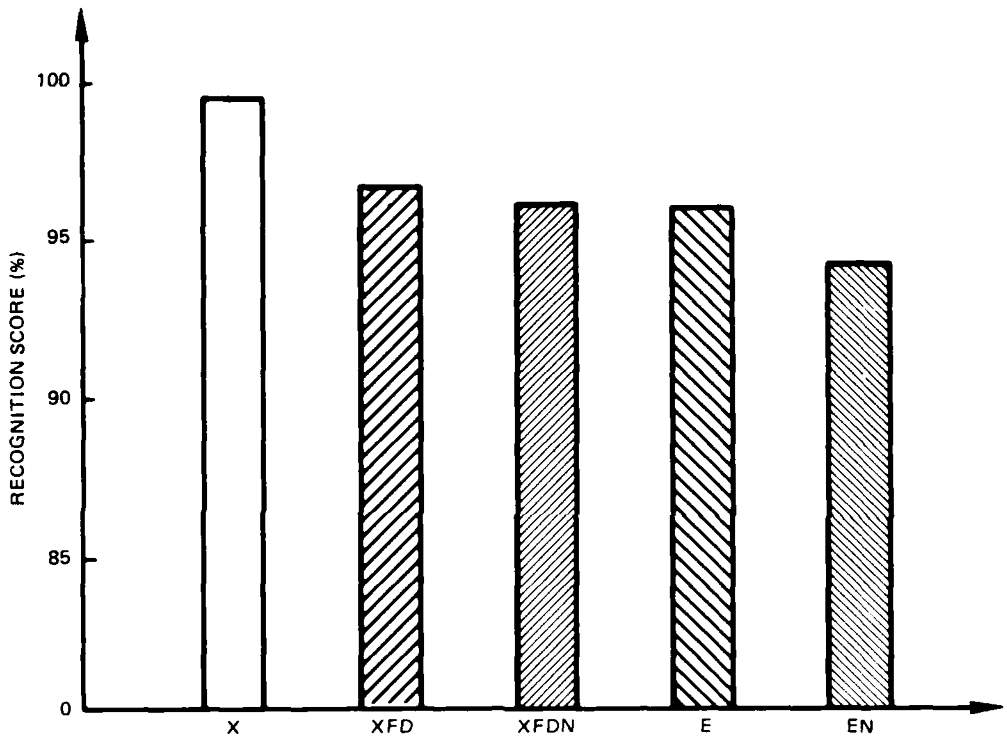
EAR COM provided isolation from noise as high as 90 dB. Noise levels of 96 dB degraded EAR COM performance. Unfortunately, two subjects performed poorly with and without noise. Clearly, EAR COM is a possible scheme for use in noise environments that prohibit the use of an external microphone. Further testing is needed to explain the wider range of subject performance with EAR COM, as compared to the external microphone.

The use of syntax created problems since recognition of words within a node depended on recognition of the node entry word. In some cases, a node had more than one entry word, and it was sometimes unclear whether a node had been erroneously exited. This can be corrected by using experienced operators and by making the entry points to a node unique and obvious. Also, some words were misunderstood more than others. The node entry points should be recognizable words that are different from other node entry words (e.g., mark and remarks were often confused).

Table A-1. Test results (Subject 1).

SUBJECT 1: MALE
TRAINING COMPLETION DATES:
EXTERNAL MICROPHONE (GAIN=3) 3/11/83
EXTERNAL MIC W/ FEEDBACK (GAIN=3) 3/11/83
EAR COM (GAIN=1; ATTENUATION=35DB) 3/14/83

| TEST | PASS | ERRORS | SCORE(%) | DATE | NOISE LEVEL (DB) | VDES GAIN (DB) | ATTEN-UATION (DB) |
|---|---|---|---|---|---|---|---|
| EXTERNAL MICROPHONE | 1 | 1 | 99.27 | 3/28/83 | | 3 | |
| | 2 | 0 | 100 | 5/11/83 | | 3 | |
| EXTERNAL MIC WITH FEEDBACK | 1 | 0 | 100 | 3/28/83 | | 3 | |
| | 2 | 2 | 98.55 | 3/28/83 | | 3 | |
| | 3 | 2 | 98.55 | 3/28/83 | | 3 | |
| | 4 | 1 | 99.26 (136 WORDS) | 4/8/83 | | 3 | |
| | 5 | 6 | 95.52 (134 WORDS) | 4/27/83 | | 3 | |
| | 6 | 4 | 97.1 | 5/18/83 | | 2 | |
| | 7 | 6 | 95.65 | 5/18/83 | | 2 | |
| | 8 | 4 | 97.1 | 5/18/83 | | 2 | |
| EXTERNAL MIC WITH FEEDBACK + NOISE | 1 | 5 | 96.38 | 4/22/83 | 80 | 2 | |
| | 2 | 4 | 97.1 | 4/22/83 | 75 | 3 | |
| | 3 | 6 | 95.65 | 4/25/83 | 80 | 2 | |
| | 4 | 5 | 96.38 | 4/25/83 | 80 | 2 | |
| | 5 | 5 | 96.38 | 4/27/83 | 80 | 2 | |
| EAR COM | 1 | 3 | 97.83 | 3/28/83 | | 1 | 35 |
| | 2 | 4 | 97.1 | 3/28/83 | | 1 | 35 |
| | 3 | 2 | 98.55 | 4/8/83 | | 1 | 35 |
| | 4 | 4 | 97.1 | 4/18/83 | | 1 | 35 |
| | 5 | 7 | 94.93 | 4/25/83 | | 1 | 35 |
| | 6 | 9 | 93.48 | 4/27/83 | | 1 | 35 |
| | 7 | 6 | 95.65 | 4/27/83 | | 1 | 35 |
| | 8 | 2 | 98.55 | 4/27/83 | | 1 | 35 |
| | 9 | 12 | 91.13 | 4/27/83 | | 1 | 35 |
| EAR COM + NOISE | 1 | 5 | 96.38 | 4/22/83 | 90 | 1 | 35 |
| | 2 | 10 | 92.75 | 4/25/83 | 80 | 1 | 35 |
| | 3 | 10 | 92.75 | 4/25/83 | 80 | 1 | 35 |
| | 4 | 14 | 89.86 | 4/27/83 | 80 | 1 | 35 |
| | 5 | 5 | 96.38 | 4/27/83 | 80 | 1 | 35 |
| | 6 | 18 | 86.9 | 5/13/83 | 96 | 1 | 35 |
| | 7 | 6 | 95.65 | 5/18/83 | 80 | 1 | 35 |
| | 8 | 4 | 97.1 | 5/18/83 | 80 | 1 | 35 |
| | 9 | 7 | 94.93 | 5/18/83 | 80 | 1 | 35 |




X = EXTERNAL MICROPHONE
XFD = EXT MIC WITH FEEDBACK
XFDN = EXT MIC WITH FEEDBACK PLUS NOISE (80 dB)
E = EAR COM
EN = EAR COM PLUS NOISE (80 dB)

*Figure A-2. Test configuration (Subject 1).*

Table A-2. Test results (Subject 2).

SUBJECT 2: MALE
TRAINING COMPLETION DATES:

| | |
|---|---|
| EXTERNAL MICROPHONE (GAIN=2) | 3/11/83 |
| EXTERNAL MIC W/ FEEDBACK (GAIN=2) | 3/14/83 |
| EAR COM (GAIN=1: ATTENUATION=40DB) | 3/16/83 |

| TEST | PASS | ERRORS | SCORE(%) | DATE | NOISE LEVEL (DB) | VDES GAIN (DB) | ATTEN-UATION (DB) |
|---|---|---|---|---|---|---|---|
| EXTERNAL MICROPHONE | 1 | 3 | 97.83 | 3/29/83 | | 2 | |
| | 2 | 4 | 97.1 | 3/29/83 | | 2 | |
| | 3 | 0 | 100 | 4/11/83 | | 2 | |
| | 4 | 1 | 99.27 | 4/18/83 | | 2 | |
| EXTERNAL MIC WITH FEEDBACK | 1 | 4 | 97.1 | 3/29/83 | | 2 | |
| | 2 | 2 | 98.55 | 4/8/83 | | 2 | |
| | 3 | 4 | 97.1 | 4/13/83 | | 2 | |
| | 4 | 1 | 99.27 | 4/27/83 | | 2 | |
| EXTERNAL MIC WITH FEEDBACK + NOISE | 1 | 6 | 95.65 | 4/22/83 | | 2 | |
| | 2 | 7 | 94.93 | 4/27/83 | | 2 | |
| | 3 | 5 | 96.38 | 5/11/83 | | 2 | |
| EAR COM | 1 | 4 | 96.95 (131 WORDS) | 3/29/83 | | 1 | 40 |
| | 2 | 7 | 94.93 | 4/8/83 | | 1 | 40 |
| | 3 | 6 | 95.65 | 4/11/83 | | 1 | 40 |
| | 4 | 9 | 93.48 | 4/27/83 | | 1 | 40 |
| EAR COM + NOISE | 1 | 5 | 96.38 | 4/22/83 | 80 | 1 | 40 |
| | 2 | 6 | 95.65 | 4/25/83 | 80 | 1 | 40 |
| | 3 | 9 | 93.48 | 4/27/83 | 80 | 1 | 40 |

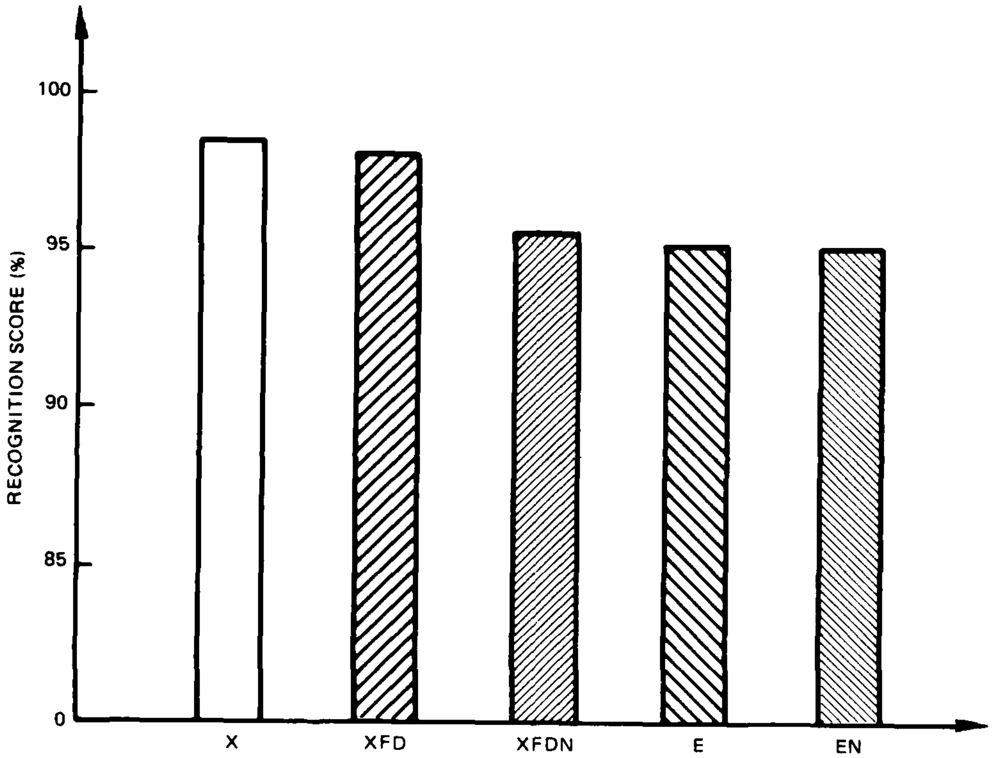



Figure A-3. Test configuration (Subject 2).

Table A-3. Test results (Subject 3).

SUBJECT 3: MALE
TRAINING COMPLETION DATES:

| | |
|---|---|
| EXTERNAL MICROPHONE (GAIN=3) | 3/11/83 |
| EXTERNAL MICROPHONE W/ FEEDBACK (GAIN=3) | 3/14/83 |
| EAR COM (GAIN=1; ATTENUATION=40DB) | 3/16/83 |

| TEST | PASS | ERRORS | SCORE (%) | DATE | NOISE LEVEL (DB) | VDES GAIN (DB) | ATTEN-UATION (DB) |
|---|---|---|---|---|---|---|---|
| EXTERNAL MICROPHONE | 1 | 24 | 82.61 | 3/29/83 | | 3 | |
| | 2 | 8 | 94.2 | 4/13/83 | | 3 | |
| EXTERNAL MIC WITH FEEDBACK | 1 | 17 | 87.68 | 3/29/83 | | 3 | |
| | 2 | 9 | 93.48 | 3/29/83 | | 3 | |
| | 3 | 12 | 91.3 | 4/13/83 | | 3 | |
| | 4 | 13 | 90.58 | 4/27/83 | | 2 | |
| | 5 | 8 | 94.2 | 5/11/83 | | 3 | |
| | 6 | 14 | 89.78 (137 WORDS) | 5/11/83 | | 2 | |
| EXTERNAL MIC WITH FEEDBACK + NOISE | 1 | 12 | 91.3 | 4/27/83 | 80 | 2 | |
| | 2 | 23 | 83.33 | 5/11/83 | 80 | 2 | |
| EAR COM | 1 | 39 | 71.74 | 3/29/83 | | 1 | 40 |
| | 2 | 47 | 65.94 | 3/29/83 | | 1 | 40 |
| | 3 | 42 | 69.56 | 4/18/83 | | 1 | 40 |
| EAR COM + NOISE | 1 | 24 | 82.61 | 4/27/83 | 80 | 1 | 40 |
| | 2 | 32 | 76.81 | 5/11/83 | 80 | 1 | 40 |

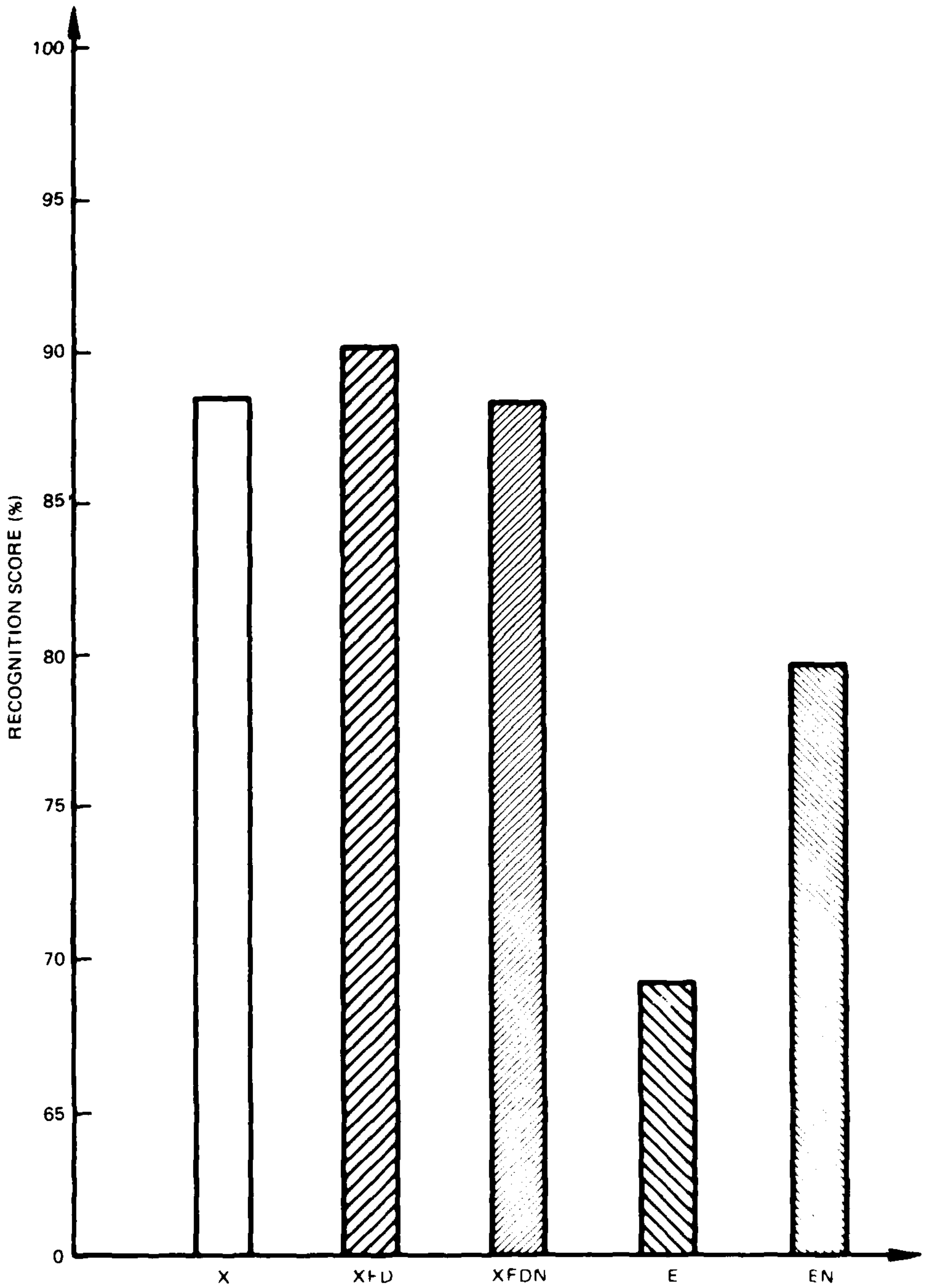



Figure A-4. Test configuration (Subject 3).

Table A-4. Test results (Subject 4).

SUBJECT 4: MALE
TRAINING COMPLETION DATES:

| | | |
|---|---|---|
| EXTERNAL MICROPHONE (GAIN=3) | | 3/11/83 |
| EXTERNAL MIC W/ FEEDBACK (GAIN=3) | | 4/11/83 |
| EAR COM (GAIN=1; ATTENUATION=40DB) | | 4/11/83 |

| TEST | PASS | ERRORS | SCORE(%) | DATE | NOISE LEVEL (DB) | VDES GAIN (DB) | ATTEN-UATION (DB) |
|---|---|---|---|---|---|---|---|
| EXTERNAL MICROPHONE | 1 | 3 | 97.83 | 4/13/83 | | 3 | |
| | 2 | 2 | 98.55 | 5/25/83 | | 3 | |
| | 3 | 5 | 96.38 | 5/25/83 | | 3 | |
| EXTERNAL MIC WITH FEEDBACK | 1 | 6 | 95.65 | 4/13/83 | | 3 | |
| | 2 | 2 | 98.55 | 5/16/83 | | 2 | |
| | 3 | 4 | 97.1 | 5/23/83 | | 2 | |
| | 4 | 3 | 97.83 | 5/23/83 | | 2 | |
| | 5 | 3 | 97.83 | 5/25/83 | | 3 | |
| | 6 | 4 | 97.1 | 5/25/83 | | 3 | |
| EXTERNAL MIC WITH FEEDBACK + NOISE | 1 | 4 | 97.1 | 4/27/83 | 80 | 2 | |
| | 2 | 3 | 97.83 | 5/11/83 | 80 | 2 | |
| | 3 | 5 | 96.38 | 5/23/83 | 80 | 2 | |
| EAR COM | 1 | 24 | 82.6 (124 WORDS) | 4/13/83 | | 1 | 40 |
| | 2 | 8 | 94.2 | 4/18/83 | | 1 | 40 |
| | 3 | 14 | 89.85 | 4/18/83 | | 1 | 40 |
| | 4 | 13 | 90.58 | 5/25/83 | | 1 | 40 |
| EAR COM + NOISE | 1 | 15 | 89.13 | 4/27/83 | 80 | 1 | 40 |
| | 2 | 14 | 89.85 | 5/11/83 | 80 | 1 | 40 |
| | 3 | 9 | 93.48 | 5/23/83 | 80 | 1 | 40 |
| | 4 | 9 | 93.48 | 5/23/83 | 80 | 1 | 40 |

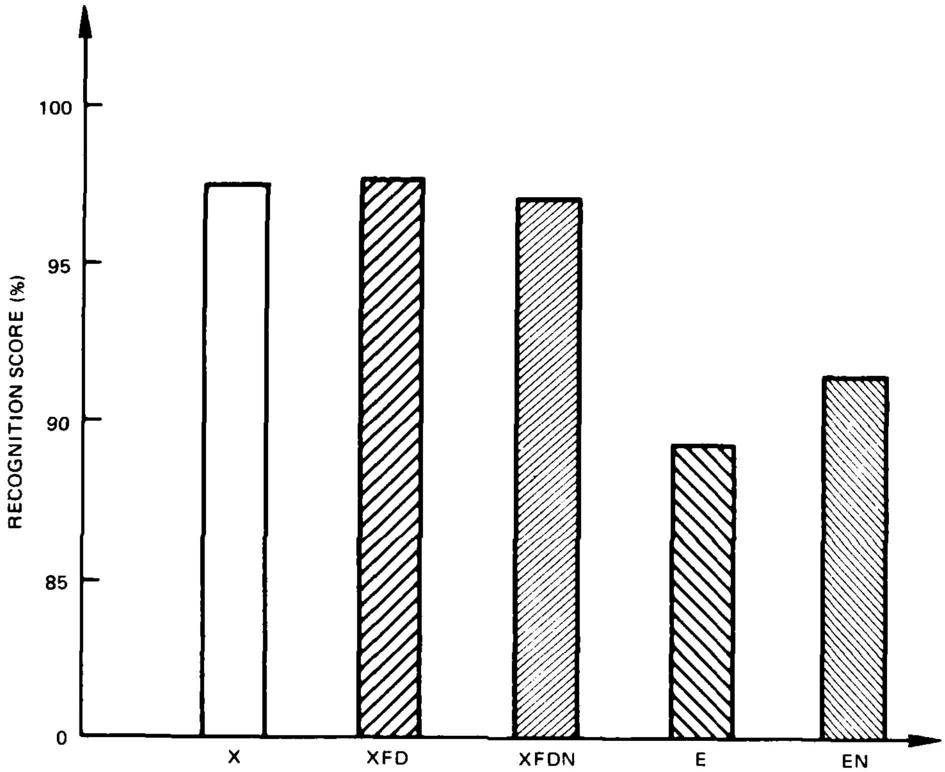



Figure A-5. Test configuration (Subject 4).

## Table A-5. Test results (Subject 5).

SUBJECT 5: FEMALE
TRAINING COMPLETION DATES:
EXTERNAL MICROPHONE (GAIN=3) 4/11/83
EXTERNAL MICROPHONE W/ FEEDBACK (GAIN=3) 4/25/83

| TEST | PASS | ERRORS | SCORE(%) | DATE | NOISE LEVEL (DB) | VDES GAIN (DB) | ATTENUATION (DB) |
|---|---|---|---|---|---|---|---|
| EXTERNAL MICROPHONE | 1 | 5 | 96.38 | 4/25/83 | | 3 | |
| | 2 | 4 | 97.1 | 5/25/83 | | 3 | |
| | 3 | 4 | 97.1 | 5/25/83 | | 3 | |
| EXTERNAL MIC WITH FEEDBACK | 1 | 17 | 87.68 | 5/11/83 | | 3 | |
| | 2 | 12 | 91.3 | 5/11/83 | | 3 | |
| | 3 | 21 | 84.78 | 5/11/83 | | 2 | |
| | 4 | 11 | 92.03 | 5/23/83 | | 2 | |
| | 5 | 17 | 87.68 | 5/25/83 | | 2 | |
| | 6 | 16 | 88.41 | 5/25/83 | | 3 | |
| EXTERNAL MIC WITH FEEDBACK + NOISE | 1 | 18 | 86.96 | 5/11/83 | 80 | 2 | |
| | 2 | 20 | 85.51 | 5/23/83 | 80 | 2 | |
| | 3 | 19 | 86.23 | 5/25/83 | 80 | 2 | |

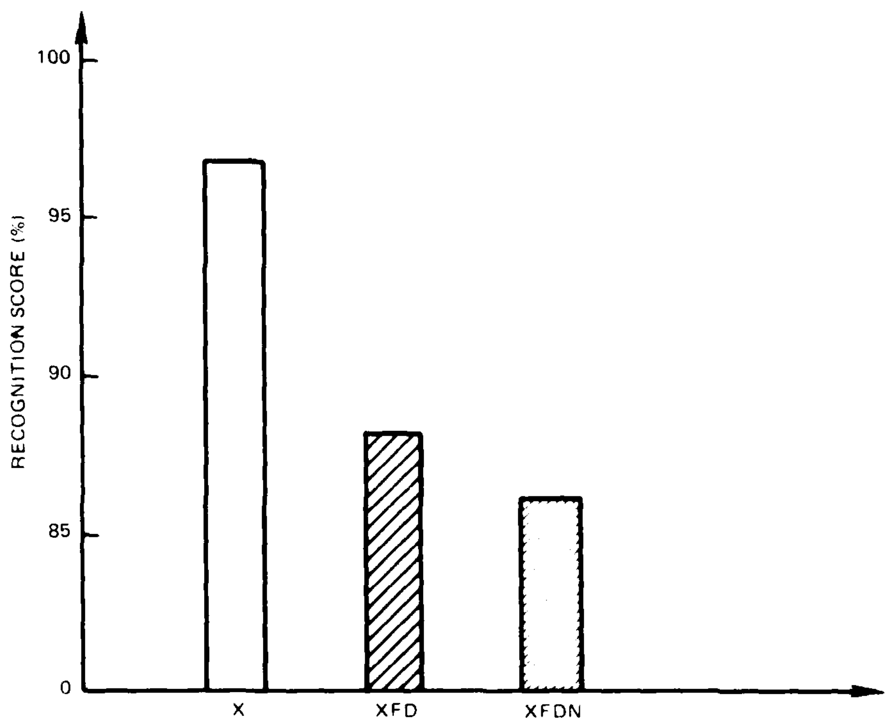



Figure A-6. Test configuration (Subject 5).

Table A-6. Mean and standard deviation for each subject.

| SUBJECT | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| TEST | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD |
| EXTERNAL MIC | 99.6 | 0.5 | 98.5 | 1.3 | 88.4 | 8.2 | 97.6 | 1.1 | 96.9 | 0.4 |
| EXTERNAL MIC WITH FEEDBACK GAIN=2 | 96.6 | 0.8 | 98.0 | 1.1 | 90.2 | 0.6 | 97.8 | 0.7 | 88.2 | 3.6 |
| EXTERNAL MIC WITH FEEDBACK GAIN=3 | 98.4 | 1.7 | | | 91.7 | 2.9 | 96.9 | 1.1 | 89.1 | 1.9 |
| EXTERNAL MIC WITH FEEDBACK + NOISE (80 dB) | 96.2 | 0.4 | 95.6 | 0.7 | 87.3 | 5.6 | 97.1 | 0.7 | 86.2 | 0.7 |
| EAR COM | 96.0 | 2.5 | 95.2 | 1.4 | 69.1 | 2.9 | 89.3 | 4.9 | | |
| EAR COM + NOISE (80 dB) | 94.2 | 2.5 | 95.2 | 1.5 | 79.7 | 4.1 | 91.5 | 2.3 | | |

$\bar{X}$=MEAN
SD=STANDARD DEVIATION

# APPENDIX B
# VDES VOICE PROGRAM

```
TYPE COMM.SR
*               DISKETTE (DOS-BASED) VDES BASE PROGRAM
*                       CONFIGURE WITH VDOS
*                       SOURCE FILE IS BASE50                   11/30/79
*              THIS PROGRAM IS FOR TACTICAL AIR REQUEST         11/18/82
*                       SOURCE FILE IS COMM (based upon BASE50)
**********************************************************************
*****************       APPLICATION VARIABLES        ******************
*****************       STANDARD USAGE 32-49    *******************
*
*  32 INPUT BUFFER ADDRESS
*  33 SELECTIVE TRAIN WORD NO.; STATISTICS TEMPORARIES (2 USES)
*  34 NO. OF PASSES FOR NEW TRAIN
*  35 SCORE OUTPUT FLAG
*  36 TALK FLAG
*  37 THRESHOLD SAVE OR CHANGE VALUE
*  38 RELAX FLAG
*  39 SYNTAX NODE POINTER WHEN RELAX SAID
*  40 NO. WORDS RECOGNIZED

*  43 NO. SCORES 120-124
*  44 NO. SCORES 115-119
*  45 NO. SCORES 110-114
*  46 NO. WINNERS BY LESS THAN 5
*  47 NO. CORRECTIONS
*  48 NO. SCORES UNDER 110
*  49 NO. CANCELS
*  56 LOOP INDEX
*
******************       APPLICATION DEPENDENT USAGE;     ***************
*                               NONE
**********************************************************************
```

```
*
;;;;;;  BEGIN CONFIGURATION PARAMETER OVERRIDES
1;190;;          190 VOCABULARY WORDS
3;3;;            1 ADDITIONAL COLUMN FOR MESSAGES
9;57;;           56 USER LOCATIONS
10;65;;          65 SUBROUTINES
12;2;;           CONFIGURE FOR POSSIBLE 2 USERS
39;4;;           LIST ON PRINTER
***********              END OVERRIDES
;;;;;;           BEGIN VOCABULARY         *********************************
* FORMAT - COL. 1=TRAINING, COL.2 = 8-BIT TRANSMIT CODES
*
RELAX;;
READY;;
ATTENTION;;
ELEVATION;<001>;;        1.
DISTANCE;<002>;;
TARGET;<003>;;
SPELL;<004>;;
UNIT CALLED;<005>;;      5.
THIS IS;<006>;;
MISSION;<007>;;
TARGET TIME;<010>;;
DESIRED RESULTS;<011>;;
TARGET LOCATION;<012>;; 10.
FINAL CONTROL;<013>;;
REQUEST NUMBER;<014>;;
REMARKS;<015>;;
ALPHA;<016>;;
BRAVO;<017>;;           15.
CHARLIE;<020>;;
DELTA;<021>;;
ECHO;<022>;;
FOXTROT;<023>;;
GOLF;<024>;;            20.
HOTEL;<025>;;
INDIA;<026>;;
JULIET;<027>;;
KILO;<030>;;
LIMA;<031>;;            25.
MIKE;<032>;;
NOVEMBER;<033>;;
OSCAR;<034>;;
PAPA;<035>;;
QUEBEC;<036>;;          30.
ROMEO;<037>;;
SIERRA;<040>;;
TANGO;<041>;;
UNIFORM;<042>;;
VICTOR;<043>;;          35.
WHISKEY;<044>;;
XRAY;<045>;;
```

```
ONE;<050>;;
TWO;<051>;;
THREE;<052>;;
FOUR;<053>;;
FIVE;<054>;;
SIX;<055>;;
SEVEN;<056>;;
EIGHT;<057>;;
NINE;<060>;;
ZERO;<061>;;
NORTH;<062>;;
SOUTH;<063>;;
EAST;<064>;;
WEST;<065>;;
ON;<066>;;
GOING;<067>;;
ARE;<070>;;
IS;<071>;;
THE;<072>;;
NO;<073>;;
NOT;<074>;;
MY;<075>;;
YOUR;<076>;;
FEET;<077>;;
METERS;<100>;;
OF;<101>;;
FROM;<102>;;
DEGREES;<103>;;
LEFT;<104>;;
RIGHT;<105>;;
SHEET;<106>;;
CHART;<107>;;
NUMBER;<110>;;
COORDINATES;<111>;;
FAR;<112>;;
CLOSE;<113>;;
GRID;<114>;;
LOCATION;<115>;;
NEAR;<116>;;
POSITION;<117>;;
SERIES;<120>;;
GO;<121>;;
BEARING;<122>;;
PREPLANNED;<123>;;
PRECEDENCE;<124>;;
PRIORITY;<125>;;
TYPE;<126>;;
RED;<127>
YELLOW;<130>;;
GREEN;<131>;;
BLACK;<132>;;
BLUE;<133>;;
WHITE;<134>;;
PURPLE;<135>;;
ORANGE;<136>;;
CODE;<137>;;
SMOKE;<140>;;
SIGNAL;<141>;;
SIGN;<142>;;
DARK;<143>;;
IMMEDIATE;<144>;;
INITIAL POINT;<145>;;
HEADING;<146>;;
OFFSET;<147>;;
```

```
MARK;<153>;;
FRIENDLIES;<154>;;
HAZARDS;<155>;;
END REMARKS;<156>;;
PERSONNEL;<157>;;
IN;<160>;;
OPEN;<161>;;
UNDER;<162>;;
COVER;<163>;;
BUILDINGS;<164>;;
BRIDGES;<165>;;
WEAPONS;<166>;;
ARTILLERY;<167>;;
MISSILES;<170>;;
ARMOR;<171>;;
VEHICLE;<172>;;
PILLBOX;<173>;;
BUNKERS;<174>;;
SUPPLIES;<175>;;
ROUTE;<176>;;
HEADQUARTERS;<177>;;
HELICOPTER;<200>;;
AIRCRAFT;<201>;;
JEEP;<202>;;
TANK;<203>;;
TRUCK;<204>;;
AMMUNITION;<205>;;
ANTI;<206>;;
GUN;<207>;;
ARMED;<210>;;
CANNON;<211>;;
DESTROY;<212>;;
NEUTRALIZE;<213>;;
BOMB;<214>;;
HARASS;<216>;;
ORDINANCE;<217>;;
ASRT;<220>;;
CALL;<221>;;
FAC;<222>;;
FREQUENCY;<223>;;
CONTROL;<224>;;
POINT;<225>;;
AFTER;<226>;;
BEFORE;<227>;;
ASAP;<230>;;
NLT;<231>;;
AT;<232>;;
AFTERNOON;<233>;;
DAY;<234>;;
EVENING;<235>;;
FROM;<236>;;
MORNING;<237>;;
NIGHT;<240>;;
NOW;<241>;;
SUN;<242>;;
SET;<243>;;
UP;<244>;;
DOWN;<245>;;
RISE;<246>;;
MOON;<247>;;
KNOTS;<250>;;
THERE;<251>;;
WEATHER;<252>;;
BAD;<253>;;
```

```
MODERATE;<256>;;
GOOD:<257>;;
TERRAIN;<260>;;
VISIBILITY;<261>;;        175.
ORDINARY;<262>;;
WIND:<263>;;              177.
*
************************END OF TRAINING VOCABULARY
;;;;;;;;;;;;;;;;;BEGIN MESSAGES ***************************
1;25;;           1 MORE COLUMN, OF MAX LENGTH 25
<15><12>;;       CR/LF            1.
WHAT ? ;;                         2.
PROMPTS ARE ON USER STATION;;     3.
  ;;    2 SPACES                  4.
XFER COMPLETE;;                   5.
TYPE DISKETTE ERROR;;             6.
SYSTEM READY;;                    7.
SYSTEM RELAXED;;                  8.
END OF TRAIN  ;;                  9.
<15><12>                  THIS IS THE BASE PROGRAM FOR VDOS VOICE%
<15><12>                                 MESSAGE ONLY;;          10.
<15><12><12><12>          STATISTICS<15><12># WORDS        = ;;   11.
<15><12># REJECTS     = ;;       12.
<15><12># 125-128     = ;;       13.
<15><12># 120-124     = ;;       14.
<15><12># 115-119     = ;;       15.
<15><12># 110-114     = ;;       16.
<15><12># CLOSE ONES  = ;;       17.
<15><12># CORRECTIONS = ;;       18.
<15><12># UNDER 110   = ;;       19.
<15><12># CANCELS     = ;;       20.
;;;;;;  END MESSAGES
;;;;;;******    BEGIN ACTION SUBROUTINES        **************************
**********************************************************************
******  THIS REGION IS STANDARD, APPLICATION INDEPENDENT
*
READ;;
=29;27;4,0;;     PRINT PROGRAM ON MODEM I/O
;;;;;;******
TRAIN;;
SFLWD;;          SET FIRST WORD AND LAST WORD NUMBERS
=38;3;2,3;;      DIRECT USER TO STATION DISPLAY FOR PROMPTS
=35;0;0;;        CLEAR REFERENCE PATTERNS
=56;-34;0;       TRAIN
;;;;;;******
ETAC;1;;
=38;9;2,3;;      END OF TRAIN MESSAGE TO CONSOLE
=45;6;2,0;;      PASSES VOCABULARY HAS BEEN TRAINED
=50;0;0;;        CLEAR FDU DISPLAY
=38;9;5,3;;      ALSO  TO FDU DISPLAY
=5;8;37;;        RESTORE THRESHOLD
;;;;;;******
UPDATE;;
SFLWD;;
=38;3;2,3;;      MESSAGE PROMPTS ON FDU DISPLAY
=56;1;0;;        1 PASS
;;;;;;******
SFLWD;;
********** NEXT LINES ARE APPLICATION DEPENDENT
=1;3;1;;         SET FIRST WORD FOR TRAINING; THIS IS STANDARD
=16;4;4;;        SET LAST WORD TO LAST COUNTED
;;;;;;******
CSAC;3;;
=5;32;27;;       COPY INPUT BUFFER ADDRESS
```

```
=38:1:2.3;;       PROVIDE CR/LF
=40:0;32;;        ACT ON INPUT BUFFER
TRTHL;;           MAKE RTHL CHANGE TYPED IN
=24:20;0;;        CONTINUE IF INPUT WAS NOT A REACTION NAME
=48:33;32;;       COMPARE INPUT WITH VOCABULARY
TESTOR;;
=25;33;0;;        CONTINUE IF MATCH FOUND
=5;3;33;;         SET 1ST WORD TO SELECTED WORD
=5;4;33;;         SET LAST WORD TO SAME
=38;3;2,3;;       PROMPTS ON USER STATION
=35;0;0;;         CLEAR PATTERN FOR SELECTED WORD ONLY
=56;0;0;          TRAIN IT
;;;;;;******
TESTOR;;
=24;33;0;;        CONTINUE IF INPUT NOT MATCHED
=38;2;2,3;;       'WHAT ?' TO CONSOLE
;;;;;;******
TRTHL;;
=27;37;-1;;       CONTINUE IF RHTL SAVE NOT NEGATIVE
=5;8;37;;         SET COMMANDED VALUE
;;;;;;******
TALK;;
=1;36;1;;         SET TALK FLAG (ENABLE VOICE RESPONSE OUTPUT)
;;;;;;******
NOTALK;;
=1;36;0;;         RESET TALK FLAG
;;;;;;******
USER1;;
=15;20;1;;        SET EXEC TO SERVICE USER # 1
;;;;;;******
USER2;;
=15;20;2;;        SET FOR USER # 2
;;;;;;******
TRACE;;
=15;22;1;;        SET TRACE FLAG
;;;;;;******
NOTRACE;;
=15;22;0;;        RESET TRACE FLAG
=57;0;100;;       DELAY FOR OUTPUT OF QUEUED TRACE LINES
;;;;;;******
RRP;;
=33;32;10,0;;     OPEN DISKETTE FILE AND READ REFERENCE PATTERNS
DERR;;
=1;1;1;;          SET RECOGNITION MODE
=38;5;2,3;;       SYSTEM READY AGAIN
;;;;;;******
WRP;;
=32;32;10.0;;     OPEN FILE AND WRITE REFERENCE PATTERNS TO DISKETTE
DERR;;
=38;5;2,3;;       MSG READY
;;;;;;******
DERR;;
=25;31;0;;        CONTINUE IF SOFT DISKETTE ERROR DETECTED
=45;31;2,0;;      OUTPUT ERROR CODE
=38;6;2,3;;       ERROR MESSAGE
=28;0;0;;         ABORT THIS PROCESSING
;;;;;;******
EXIT;;
=41;0;0;          RETURN TO OPERATING SYSTEM
;;;;;;******
INIT;;
=41;0;1;          RECONFIGURE
;;;;;;******
PEEK;;
```

```
POKE;;
=30;32;5;           CHANGE SPECIFIED USER LOCATION AS SPECIFIED
;;;;;;******
SCORE;;
=1;35;1;;           SET FLAG TO OUTPUT SCORES
;;;;;;******
NOSCORE;;
=1;35;0;;           RESET SCORE OUTPUT FLAG
;;;;;;******
CLEARSTATS;;        ZERO ALL TALLIES
=12;40;10;;
;;;;;;******
PRINTSTATS;;        PRINT RECOGNITION STATISTICS SINCE CLEARED
=15;25;0;;          ZERO EOL STRING
=38;11;2,3;;
=45;40;2,0;;        TOTAL
=38;12;2,3;;
=45;41;2,0;;        REJECTS
=38;13;2,3;;
=45;42;2,0;;        125-128
=38;14;2,3;;
=45;43;2,0;;        120-124
=38;15;2,3;;
=45;44;2,0;;        115-119
=38;16;2,3;;
=45;45;2,0;;        110-114
=38;17;2,3;;
=45;46;2,0;;        CLOSE ONES
=38;18;2,3;;
=45;47;2,0;;        CORRECTIONS
=38;19;2,3;;
=45;48;2,0;;        UNDER 110
=38;20;2,3;;
=45;49;2,0;;        CANCELS
=38;1;2,3;;         CR/LF
=57;0;250;;         WAIT UNTIL OUTPUT COMPLETE
=15;25;<6412>;;     RESTORE CRLF EOL STRING
;;;;;;******
SCACT1;;            FIND RANGE IN WHICH CURRENT SCORE FITS
TCLOSE;;            TALLY CLOSE ONES
=1;33;42;;          SET TALLY BUCKET FOR 125-128
=26;18;125;;        CONTINUE IF SCORE LESS
=1;33;43;;          NOW SET FOR 120-124
=26;18;120;;        CONTINUE IF LESS
=1;33;44;;          SET FOR 115-119
=26;18;115;;        CONTINUE IF LESS
=1;33;45;;          SET FOR 110-114
=26;18;110;;        CONTINUE IF LESS
=1;33;48;;          SET BUCKET FOR LESS THAN 110
;;;;;;******
TCLOSE;;
=5;33;18;;          GET WINNING SCORE
=7;33;30;;          SUBTRACT 1ST RUNNERUP SCORE
=26;33;5;;          CONTINUE IF DIFFERENCE LESS THAN 5
=2;46;1;;           INCREMENT CLOSE ONES TALLY
;;;;;;******
SCACT2;;
=23;33;1;;          INCREMENT APPROPRIATE SCORE RANGE TALLY
=25;35;0;;          CONTINUE IF SCORES TO BE OUTPUT
=15;25;0;;          ZERO EOL STRING
=38;1;2,3;;         ASSURE NEW LINE
=37;5;2,1;;         OUTPUT ITEM RECOGNIZED TO CONSOLE
=38;4;2,3;;         SPACING
=45;18;2,0;;        SCORE OF WINNER
```

```
=37;30;2,1;;     1ST RUNNERUP ASCII
=38;4;2,3;;
=45;31;2,0;;     1ST RUNNERUP SCORE
=38;1;2,3;;      ASSURE NEW LINE
=57;0;250;;      WAIT UNTIL OUTPUT COMPLETE
=15;25;<6412>;;  RESTORE CRLF EOL STRING
;;;;;;******
*
RTHL0;;          SET RTHL=0
=1;37;0;;
;;;;;*****
*
RTHL100;;        SET RTHL=100
=1;37;100;;
;;;;;*****
*
RTHL105;;        SET RTHL=105
=1;37;105;;
;;;;;*****
*
RTHL110;;        SET RTHL=110
=1;37;110;;
;;;;;*****
*
RTHL115;;        SET RTHL=115
=1;37;115;;
;;;;;*****
*
RTHL120;;        SET RTHL=120
=1;37;120;;
;;;;;*****
*
RTHL125;;        SET RTHL=125
=1;37;125;;
;;;;;*****
*
TP1;;
=1;34;1;;        SET FOR 1 PASS PER NEW TRAIN
;;;;;*****
TP2;;
=1;34;2;;        SET FOR 2 PASSES
;;;;;*****
TP3;;
=1;34;3;;        SET FOR 3 PASSES
;;;;;*****
TP5;;
=1;34;5;;        SET FOR 5 PASSES
;;;;;*****

**
******  THIS SECTION CONTAINS APPLICATION CODE  ************************
******           BEGINNING WITH TRIGGERED SUBROUTINES    ***************
* SUBROUTINE NAMES BEGINNING WITH 'Z' RESPOND DIRECTLY TO INPUT SPEECH
*
LOOPI;2;;       SEQUENCE THRU VOCAB AUTO AND OUTPUT
=27;55;0;;       CONTUNUE IF INDEX GR THAN 0
LOOP;;           CALL LOOP FOR ONE PASS THRU VOCAB
=26;56;4;;       CONT IF UL56 LT 4, BUMP VOCAB IND TO 257
=1;56;257;;     257 IS VOCAB SIZE
=2;55;-1;;       DECR LOOPI COUNT
;;;;;;******
LOOP;;
=27;56;3;;       CONT IF IND GR THAN 3
=50;0;0;;        CLEAR FDU
```

```
=43;0;0;;          WAIT
=15;25;3338;;      REPLACE CR/LF
=57;0;2000;;       DELAY 1 SECOND
=2;56;-1;;         DECREMENT LOOP COUNT
;;;;;;******
EIAC;6;8;;         EXECUTED AFTER LOADS, AND AFTER CONFIGURATION
=1;1;1;;           SET RECOGNITION MODE
=50;0;0;;          CLEAR FDU DISPLAY
=38;7;5,3;;        MSG SYSTEM READY
=38;10;2,3;;       SIMPLE GREETING TO CONSOLE
=1;34;3;;          SET DEFAULT 3 TRAINING PASSES
=1;8;110;;         SET DEFAULT 110 THRESHOLD
=1;7;$XCONTROL;;          SET SYNTAX NODE TO XCONTROL
;;;;;;******
ITAC;9;;           EXECUTED WHEN INTERRUPT BUTTON IS PRESSED
TRAIN;;            MAKE COMMON USE OF IT AS "TRAIN" BUTTON
;;;;;;******
DFAC;0;;           EXECUTED UPON RECOGNITION IF NO OTHER ACTION SPECIFII
=5;39;7;           REMEMBER SYNTAX IN CASE NEXT WORD IS RELAX
=50;0;0;;          CLEAR FDU DISPLAY
=37;5;5,1;;        DISPLAY WORD RECOGNIZED
=15;25;0;;        DEFEAT CR/LF AT OUTPUT
=37;5;3,2;;        8-BIT CODE TO SYSTEM I/O
=57;0;250;;          WAIT FOR OUTPUT
=15;25;3338;;      REPLACE CR/LF
SCACT1;;           ACCUMULATE SCORING COUNTS
SCACT2;;           PRINT SCORES IF ENABLED
=2;40;1;;         INCREMENT RECOGNITION TALLY
;;;;;;******
NFAC;7;;           EXECUTED IF BEST SCORE DOES NOT EXCEED THRESHOLD; REJEC
=24;38;0;;         CONTINUE IF RELAX NOT SET
=2;41;1;;          INCREMENT REJECT TALLY
=50;0;0;;          CLEAR FDU DISPLAY
=38;2;5,3;;        WHAT?
=57;0;750;;        GIVE TIME TO SEE MESSAGE
=50;0;0;;          CLEAR AGAIN
=37;5;5,1;;        REPLACE WITH LAST RECOGNITION
;;;;;;******
**********         FOLLOWING ARE RESPONSES TO CONTROL WORDS        *******
ZRELAX;;
SCACT1;
SCACT2;
=1;38;1;;          SET RELAX FLAG
=38;8;2,3;;        NOTIFICATION TO CONSOLE
=57;0;750;;        GIVE TIME TO SEE VERIFICATION
=50;0;0;;          CLEAR FDU DISPLAY
=38;8;5,3;;        MESSAGE TO STATION
;;;;;;******
ZREADY;;           ONLY ATTENTION WILL BE RECOGNIZED NOW
SCACT1;
SCACT2;
;;;;;;******
ZATTENTION;;
SCACT1;
SCACT2;
=1;38;0;;          RESET RELAX FLAG
=38;7;2,3;;        NOTIFY SYTEM READY AT CONSOLE
=57;0;750;;        GIVE TIME TO SEE VERIFICATION
=50;0;0;;          CLEAR FDU DISPLAY
=38;7;5,3;;        SYSTEM READY MESSAGE AT USER STATION
=5;7;39;;          RESTORE SYNTAX IN EFFECT WHEN SYSTEM WENT INTO RELAX
;;;;;;******
;;;;;;;;;;;        SYNTAX NODE DESCRIPTIONS BEGIN  **********************
```

```
RELAX:XREADY;ZRELAX;;
TARGET:XTARGET;;
SPELL;XSPELL;;
UNIT CALLED:XUNITCALL;;
THIS IS;XUNITCALL;;
MISSION;XMISSION;;
TARGET TIME;XTARGETTIME;;
DESIRED RESULTS;XDESIRESULTS;;
TARGET LOCATION;XTRGTLOC;;
FINAL CONTROL;XFNLCTRL;;
REQUEST NUMBER;XUNITCALL;;
REMARKS;XREMARKS;;
;;;;;;******
XSPELL;;;
SPELL;;;
CONTROL;XCONTROL;;;
REMARKS;XREMARKS;;
ALPHA;;;
BRAVO;;;
CHARLIE;;;
DELTA;;;
ECHO;;;
FOXTROT;;;
GOLF;;;
HOTEL;;;
INDIA;;;
JULIET;;;
KILO;;;
LIMA;;;
NOVEMBER;;;
OSCAR;;;
PAPA;;;
QUEBEC:;;
ROMEO;;;
SIERRA;;;
TANGO;;;
UNIFORM;;;
VICTOR;;;
WHISKEY;;;
XRAY;;;
YANKEE;;;
ZULU;;;
;;;;;;******
XUNITCALL;;;
TARGET;XTARGET;;
SPELL;XSPELL;;
UNIT CALLED;;;
THIS IS;;;
MISSION:XMISSION;;
TARGET TIME;XTARGETTIME;;
DESIRED RESULTS;XDESIRESULTS;;
TARGET LOCATION;XTRGTLOC;;
FINAL CONTROL;XFNLCTRL;;
REQUEST NUMBER;;;
REMARKS;XREMARKS;;
CONTROL;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ALPHA;;;
BRAVO;;;
CHARLIE;;;
DELTA;;;
ECHO;;;
FOXTROT;;;
GOLF;;;
```

```
KILO;;;
LIMA;;;
MIKE;;;
NOVEMBER;;;
PAPA;;;
QUEBEC;;;
ROMEO;;;
SIERRA;;;
TANGO;;;
UNIFORM;;;
VICTOR;;;
WHISKEY;;;
XRAY;;;
YANKEE;;;
ZULU;;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
;;;;;;******
XMISSION;;;
TARGET;XTARGET;;
SPELL;XSPELL;;
UNIT CALLED;XUNITCALL;;
THIS IS;XUNITCALL;;
MISSION;;;
TARGET TIME;XTARGETTIME;;
DESIRED RESULTS;XDESIRESULTS;;
TARGET LOCATION;XTRGTLOC;;
FINAL CONTROL;XFNLCTRL;;
REQUEST NUMBER;XUNITCALL;;
REMARKS;XREMARKS;;
CONTROL;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
IMMEDIATE;;;
IS;;;
NO;;;
NOT;;;
PRECEDENCE;;;
PRIORITY;;;
PREPLANNED;;;
THE;;;
;;;;;;******;;;
XTARGET;;;
TARGET;;;
SPELL;XSPELL;;
UNIT CALLED;XUNITCALL;;
THIS IS;XUNITCALL;;
```

```
DESIRED RESULTS;XDESIRESULTS;;
TARGET LOCATION;XTRGTLOC;;
FINAL CONTROL;XFNLCTRL;;
REQUEST NUMBER;XUNITCALL;;
REMARKS;XREMARKS;;
CONTROL;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
PERSONNEL;;;
IN;;;
OPEN;;;
UNDER;;;
COVER;;;
WEAPONS;;;
ARTILLERY;;;
MISSILES;;;
ARMOR;;;
VEHICLE;;;
BUILDINGS;;;
BRIDGES;;;
PILLBOX;;;
BUNKERS;;;
SUPPLIES;;;
ROUTE;;;
NORTH;;;
SOUTH;;;
EAST;;;
WEST;;;
HEADQUARTERS;;;
HELICOPTER;;;
AIRCRAFT;;;
JEEP;;;
TANK;;;
TRUCK;;;
AMMUNITION;;;
ANTI;;;
GUN;;;
ARMED;;;
CANNON;;;
ON;;;
GOING;;;
ARE;;;
IS;;;
THE;;;
NO;;;
NOT;;;
;;;;;;******
XTARGETTIME;;;
TARGET;XTARGET;;
SPELL;XSPELL;;
UNIT CALLED;XUNITCALL;;
THIS IS;XUNITCALL;;
MISSION;XMISSION;;
TARGET TIME;;;
DESIRED RESULTS;XDESIRESULTS;;
```

```
REQUEST NUMBER;XUNITCALL;;
REMARKS;XREMARKS;;
CONTROL;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
ASAP;;;
NLT;;;
AT;;;
AFTERNOON;;;
DARK;;;
DAY;;;
EVENING;;;
FROM;;;
IMMEDIATE;;;
MORNING;;;
NIGHT;;;
NOW;;;
SUN;;;
RISE;;;
SET;;;
UP;;;
DOWN;;;
MOON;;;
IS;;;
;;;;;;******
XDESIRESULTS;;;
UNIT CALLED;XUNITCALL;;
TARGET;XTARGET;;
SPELL;XSPELL;;
THIS IS;XUNITCALL;;
MISSION;XMISSION;;
DESIRED RESULTS;;;
TARGET LOCATION;XTRGTLOC;;
TARGET TIME;XTARGETTIME;;
FINAL CONTROL;XFNLCTRL;;
REQUEST NUMBER;XUNITCALL;;
REMARKS;XREMARKS;;
CONTROL;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ORDINANCE;;;
DESTROY;;;
NEUTRALIZE;;;
HARASS;;;
BOMB;;;
ARE;;;
;;;;;;******
XTRGTLOC;;;
TARGET;XTARGET;;
SPELL;XSPELL;;
UNIT CALLED;XUNITCALL;;
THIS IS;XUNITCALL;;
MISSION;XMISSION;;
TARGET TIME;XTARGETTIME;;
DESIRED RESULTS;XDESIRESULTS;;
TARGET LOCATION;XTRGTLOC;;
```

```
REMARKS;XREMARKS;;
CONTROL;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
METERS;;;
FEET;;;
ELEVATION;;;
SHEET;;;
NUMBER;;;
SERIES;;;
CHART;;;
COORDINATES;;;
DISTANCE;;;
FAR;;;
CLOSE;;;
FROM;;;
GRID;;;
LOCATION;;;
NEAR;;;
NORTH;;;
SOUTH;;;
EAST;;;
WEST;;;
POSITION;;;
ON;;;
GOING;;;
ARE;;;
IS;;;
THE;;;
NO;;;
NOT;;;
MY;;;
YOUR;;;
OF;;;
DEGREES;;;
LEFT;;;
RIGHT;;;
;;;;;;******
XFNLCTRL;;;
TARGET;XTARGET;;
SPELL;XSPELL;;
UNIT CALLED;XUNITCALL;;
THIS IS;XUNITCALL;;
MISSION;XMISSION;;
TARGET TIME;XTARGETTIME;;
DESIRED RESULTS;XDESIRESULTS;;
TARGET LOCATION;XTRGTLOC;;
FINAL CONTROL;;;
REQUEST NUMBER;XUNITCALL;;
REMARKS;XREMARKS;;
CONTROL;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
```

```
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
FAC;;;
CALL;;;
SIGN;;;
FREQUENCY;;;
ASRT;;;
CONTROL;;;
POINT;;;
IS;;;
;;;;;;******
XREMARKS;;;
INITIAL POINT;XINITPT;;
HEADING;XHDG;;
OFFSET;XHDG;;
DISTANCE;XINITPT;;
ELEVATION;XELEV;;
DESCRIPTION;XDESCR;;
MARK;XMARK;;
TIME ON TARGET;XTIMEONTARG;;
DESCRIPTION;XDESCR;;
MARK;XMARK;;
TIME ON TARGET;XTIMEONTARG;;
FRIENDLIES;XINITPT;;
HAZARDS;XHZRDS;;
SPELL;XSPELL;;
END REMARKS;XCONTROL;;
RELAX;XREADY;ZRELAX;;
;;;;;;******
XINITPT;;;
INITIAL POINT;;;
HEADING;XHDG;;
OFFSET;XHDG;;
DISTANCE;XINITPT;;
ELEVATION;YELEV;;
DESCRIPTION;XDESCR;;
MARK;XMARK;;
TIME ON TARGET;XTIMEONTARG;;
FRIENDLIES;XINITPT;;
HAZARDS;XHZRDS;;
REMARKS;XREMARKS;;
END REMARKS;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
METERS;;;
FEET;;;
ELEVATION;;;
SHEET;;;
NUMBER;;;
SERIES;;;
CHART;;;
COORDINATES;;;
```

```
CLOSE;;;
FROM;;;
GRID;;;
LOCATION;;;
NEAR;;;
NORTH;;;
SOUTH;;;
EAST;;;
POSITION;;;
ON;;;
GOING;;;
ARE;;;
IS;;;
THE;;;
NO;;;
NOT;;;
MY;;;
YOUR;;;
OF;;;
DEGREES;;;
LEFT;;;
RIGHT;;;
TARGET;;;
;;;;;;******
XHDG;;;
INITIAL POINT;XINITPT;;
HEADING;;;
OFFSET;XHDG;;
DISTANCE;XINITPT
ELEVATION;XELEV;;
DESCRIPTION;XDESCR;;
MARK;XMARK;;
TIME ON TARGET;XTIMEONTARG;;
FRIENDLIES;XINITPT;;
HAZARDS;XHZRDS;;
SPELL;XSPELL;;
REMARKS;XREMARKS;;
END REMARKS;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
DEGREES;;;
LEFT;;;
RIGHT;;;
IS;;;
NORTH;;;
SOUTH;;;
EAST;;;
WEST;;;
GOING;;;
TARGET;;;
GO;;;
;;;;;;******
XELEV;;;
INITIAL POINT;XINITPT;;
HEADING;XHDG;;
```

```
ELEVATION;;
DESCRIPTION;XDESCR;;
MARK:XMARK;;
TIME ON TARGET;XTIMEONTARG;;
FRIENDLIES;XINITPT;;
HAZARDS;XHZRDS;;
SPELL;XSPELL;;
REMARKS;XREMARKS;;
END REMARKS;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
FEET;;;
METERS;;;
TARGET;;;
IS;;;
;;;;;;******
XDESCR;;;
INITIAL POINT;XINITPT;;
HEADING;XHDG;;
OFFSET;XHDG;;
DISTANCE;XINITPT;;
ELEVATION;XELEV;;
DESCRIPTION;;;
MARK;XMARK;;
TIME ON TARGET;XTIMEONTARG;;
FRIENDLIES;XINITPT;;
HAZARDS;XHZRDS;;
SPELL;XSPELL;;
REMARKS;XREMARKS;;
END REMARKS;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
PERSONNEL;;;
IN;;;
OPEN;;;
UNDER;;;
COVER;;;
WEAPONS;;;
ARTILLERY;;;
MISSILES;;;
ARMOR;;;
VEHICLE;;;
BUILDINGS;;;
BRIDGES;;;
PILLBOX;;;
BUNKERS;;;
```

```
NORTH;;;
SOUTH;;;
EAST;;;
WEST;;;
HOTEL;;;
HEADQUARTERS;;;
HELICOPTER;;;
AIRCRAFT;;;
JEEP;;;
TANK;;;
TRUCK;;;
VEHICLE;;;
AMMUNITION;;;
ANTI;;;
GUN;;;
ARMED;;;
CANNON;;;
ON;;;
GOING;;;
ARE;;;
IS;;;
THE;;;
NO;;;
NOT;;;
TARGET;;;
;;;;;;******
XMARK;;;
INITIAL POINT;XINITPT;;
HEADING;XHDG;;
OFFSET;XHDG;;
DISTANCE;XINITPT;;
ELEVATION;XELEV;;
DESCRIPTION;XDESCR;;
MARK;XMARK;;
TIME ON TARGET;XTIMEONTARG;;
FRIENDLIES;XINITPT;;
HAZARDS;XHZRDS;;
SPELL;XSPELL;;
REMARKS;XREMARKS
END REMARKS;XCONTROL;;
RELAX;XREADY;ZRELAX;;
TYPE;;;
RED;;;
YELLOW;;;
GREEN;;;
BLACK;;;
WHITE;;;
PURPLE;;;
ORANGE;;;
BLUE;;;
CODE;;;
ONE;;;
TWO;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
SMOKE;;;
SIGN;;;
SIGNAL;;;
IS;;;
```

```
INITIAL POINT;XINITPT;;
HEADING;XHDG;;
OFFSET;XHDG;;
DISTANCE;XINITPT;;
ELEVATION;XELEV;;
DESCRIPTION;XDESCR;;
MARK;XMARK;;
TIME ON TARGET;;;
FRIENDLIES;XINITPT;;
HAZARDS;XHZRDS;;
SPELL;XSPELL;;
REMARKS;XREMARKS;;
END REMARKS;XCONTROL;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
FIVE;;;
SIX;;;
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
ASAP;;;
NLT;;;
AT;;;
AFTERNOON;;;
DARK;;;
DAY;;;
EVENING;;;
FROM;;;
IMMEDIATE;;;
MORNING;;;
NIGHT;;;
NOW;;;
SUN;;;
RISE;;;
SET;;;
UP;;;
DOWN;;;
MOON;;;
RISE;;;
TARGET;;;
RELAX;XREADY;ZRELAX;;
;;;;;;******
XHZRDS;;;
INITIAL POINT;XINITPT;;
HEADING;XHDG;;;
OFFSET;XHDG;;
DISTANCE;XINITPT;;
ELEVATION;XELEV;
DESCRIPTION;XDESCR;;
MARK;XMARK;;
TIME ON TARGET;XTIMEONTARG;;
FRIENDLIES;XINITPT;;
HAZARDS;;;
SPELL;XSPELL;;
REMARKS;XREMARKS;;
END REMARKS;XCONTROL;;
RELAX;XREADY;ZRELAX;;
ONE;;;
TWO;;;
THREE;;;
FOUR;;;
```

```
SEVEN;;;
EIGHT;;;
NINE;;;
ZERO;;;
WIND;;;
WEATHER;;;
BAD;;;
COLD;;;
HOT;;;
DARK;;;
MODERATE;;;
ORDINARY;;;
GOOD;;;
TERRAIN;;;
VISIBILITY;;;
METERS;;;
FEET;;;
NORTH;;;
SOUTH;;;
EAST;;;
WEST;;;
ARE;;;
IS;;;
THE;;;
NO;;;
NOT;;;
;;;;;;******
XREADY;;;
READY;XATTENTION;ZREADY;;
;;;;;;******
XATTENTION;;;
ATTENTION;XATTENTION;ZATTENTION;;
;;;;;;******
;;;;;;;;;;       END OF PROGRAM          **********************
R
```

# APPENDIX C
# USMC VOCABULARY

A
ADMIN
AFFIRMATIVE
AFTER
AFTERNOON
AGAIN
AGENCY
AIR
AIRBORNE
AIRCRAFT
ALERT
ALL
ALPHA
ALTERNATE
AM
AMMUNITION
AN
ANSWER
ANTI
ARE
ARMED
ARTILLERY
AT
ATTACK

BAD
BATTALION
BEARING
BLACK
BLUE
BOMB
BRAVO
BRIGADE

CALL
CANNON
CANTCO
CAPTURED
CEASE
CHARLIE
CLOSE
COLD
COLUMN
COMMAND
COMMENCE
COMPANY
CONTACT
CONTROL
COORDINATE
COORDINATES
CORPSMAN
CORRECTION
COVER

DARK
DAY
DECIMAL
DECK
DEGREE
DELTA
DESTROY
DIRECT
DIRECTION
DISTANCE
DIVISION
DOWN

EAST
ECHO
EIGHT
ELECTRONIC
ELEMENT
EMERGENCY
ENEMY
EVENING

FALL
FAR
FIRE
FIVE
FLAK
FOOD
FOREWARD
FOUR/FOR
FOXTROT
FREQUENCY
FRIENDLY
FROM
FUSE

GO
GOING
GOLF
GOOD
GREEN
GRENADE
GRID
GROUND
GROUP
GUN

HAVE
HEADING
HEADQUARTERS
HEAVY
HELICOPTER
HELP
HOSTILE
HOT
HOTEL

I
IMMEDIATE
INDIA
INFANTRY
INJURED
INTELLIGENCE
IS

JEEP
JULIET

KILLED
KILO
KNOTS
LEFT
LIGHT
LIMA
LOCATION
LOGISTICS
LUBRICANTS

MAB
MAF
MAG
MAN
MAU
ME
METERS
METRO
MIKE
MILL
MISSION
MODERATE
MOON
MORNING

NAPALM
NAVAL
NEAR
NEGATIVE
NEUTRALIZE
NIGHT
NINE
NO
NORTH
NOT
NOVEMBER
NOW
NUMBER

OIL
ON
ONE
OPERATIONS
ORANGE
ORDINARY
ORGANIZE
OSCAR
OUT
OVER

PAPA
PARAMETERS
PERSONNEL
PETROLEUM
PLAN
PLATOON
POSITION
PREPLANNED
PURPLE

QUEBEC
QUICK

RADAR
RADIO
RANGE
RECEIVED
RECON
RED
REGIMENT
REPEAT
REPLACEMENT
REQUEST
REVERSE
RIFLE
RIGHT
RISE
ROCKET
ROGER
ROMEO
RUN

SAY
SEARCH
SEND
SENT
SET
SEVEN
SHOT
SIERRA
SIGN
SIGNAL
SITUATION
SIX
SMOKE
SOUTH
SPECIFIC
SPELL
SQUAD
SQUADRON
STANDBY
STRAFE
SUN
SUPPLY
SYSTEM

TACTICAL
TANGO
TANK
TARGET
TEAM
TERRAIN
TEST
THE
THERE
THIS
THREE
TIME
TRACKED
TRAINING
TRANSMISSION
TRUCK
TWO/TO
TYPE

UNDER
UNIFORM
UNIT
UP
URGENT

VEHICLE
VICTOR
VT

WAIT
WANT
WARM
WEST
WHEELED
WHISKEY
WHITE
WILCO
WING
WOUNDED

X RAY

YANKEE
YELLOW
YOU

ZERO
ZULU

| 26-WORD VOCABULARY | 10-WORD VOCABULARY |
|---|---|
| ALPHA | ONE |
| BRAVO | TWO |
| CHARLIE | THREE |
| DELTA | FOUR |
| ECHO | FIVE |
| FOXTROT | SIX |
| GOLF | SEVEN |
| HOTEL | EIGHT |
| INDIA | NINE |
| JULIET | ZERO |
| KILO | |
| LIMA | |
| MIKE | |
| NOVEMBER | |
| OSCAR | |
| PAPA | |
| QUEBEC | |
| ROMEO | |
| SIERRA | |
| TANGO | |
| UNIFORM | |
| VICTOR | |
| WHISKEY | |
| XRAY | |
| YANKEE | |
| ZULU | |

UNTRAINED WORDS USED FOR FALSE RECOGNITION TEST

| | | | |
|---|---|---|---|
| ABSOLUTE | GROWL | NOISY | UMBRELLA |
| ACKNOWLEDGE | HOWITZER | NUCLEUS | UNDERLINE |
| AMBUSH | HIT-AND-RUN | OBSERVE | UPHILL |
| BATTERY | HOUSE | OFTEN | VALVE |
| BOMBARD | IDENTICAL | ORIENT | VERBAL |
| BULLETIN | INTERLEAVE | PACE | VULNERABLE |
| CANYON | ISSUE | PERIOD | WADE |
| COAXIAL | JAM | PHOTOGRAPH | WALK |
| COMMANDING OFFICER | JIGSAW | QUADRANT | WIND |
| DANGER | JOT | QUENCH | XENON |
| DETERMINE | KEEP | QUOTE | XEROX |
| DOWNRANGE | KEY | RAIN | XRATED |
| EARLY | KNOLL | REGULATE | YESTERDAY |
| EIGHTEEN | LEADER | RIDGE | YOUR |
| EMBARK | LEVEL | SAFE | YOUNG |
| FACTORY | LAID | SCHOOL | ZOO |
| FIGURE | MACHINE | SOLUTION | ZIPPER |
| FREEZE | MATCH | TABLE | ZONE |
| GRANITE | MOUNTAIN | THEORY | |
| GRIDDLE | NETWORK | TOLERATE | |

TEST MESSAGE

X = NODE

| | | |
|---|---|---|
| 1X | UNIT CALLED | |
| 2 | | ALPHA |
| 3 | | ONE |
| 4 | | SIX |
| 5 | | BRAVO |
| 6 | | THIS IS |
| 7 | | TANGO |
| 8 | | ECHO |
| 9 | | DELTA |
| 10 | | REQUEST NUMBER |
| 11 | | THREE |
| 12X | MISSION | |
| 13 | | IS |
| 14 | | IMMEDIATE |
| 15 | | PRIORITY |
| 16 | | ONE |
| 17X | TARGET | |
| 18 | | IS |
| 19 | | WEST |
| 20 | | HEADQUARTERS |
| 21X | TARGET TIME | |
| 22 | | IS |
| 23 | | EVENING |
| 24 | | AT |
| 25 | | TWO |
| 26 | | THREE |
| 27 | | ZERO |
| 28 | | ZERO |
| 29X | TARGET LOCATION | |
| 30 | | COORDINATES |
| 31 | | TWO |
| 32 | | DEGREES |
| 33 | | EAST |
| 34 | | CHART |
| 35 | | NUMBER |
| 36 | | NINE |
| 37 | | ELEVATION |
| 38 | | SEVEN |
| 39 | | FEET |
| 40X | FINAL CONTROL | |
| 41 | | IS |
| 42 | | FAC |
| 43X | REMARKS | |
| 44X | INITIAL POINT | |
| 45 | | POSITION |
| 46 | | ZERO |
| 47X | HEADING | |
| 48 | | EAST |
| 49X | ELEVATION | |
| 50 | | IS |
| 51 | | FIVE |
| 52 | | METERS |
| 53X | DESCRIPTION | |
| 54 | | PILLBOX |
| 55X | MARK | |
| 56 | | TYPE |
| 57 | | IS |
| 58 | | RED |
| 59X | TIME ON TARGET | |
| 60 | | DAY |
| 61 | | ASAP |
| 62X | HAZARDS | |
| 63 | | BAD |
| 64 | | WEATHER |
| 65 | | COLD |
| 66 | | FEET |
| 67X | END REMARKS | |
| 68X | UNIT CALLED | |
| 69 | | ZULU |
| 70 | | SIX |
| 71 | | WHISKEY |
| 72 | | THIS IS |
| 73 | | ROMEO |
| 74 | | INDIA |
| 75 | | CHARLIE |
| 76 | | KILO |
| 77 | | REQUEST NUMBER |
| 78 | | SEVEN |
| 79X | MISSION | |
| 80 | | IS |
| 81 | | PREPLANNED |
| 82X | TARGET | |
| 83 | | IS |
| 84 | | IN |
| 85 | | BUILDINGS |
| 86X | TARGET TIME | |
| 87 | | IS |
| 88 | | MORNING |
| 89 | | AT |
| 90 | | ONE |
| 91 | | TWO |
| 92 | | THREE |
| 93X | DESIRED RESULTS | |
| 94 | | NEUTRALIZE |
| 95X | TARGET LOCATION | |
| 96 | | NINE |
| 97 | | METERS |
| 98 | | SOUTH |
| 99 | | CHART |
| 100 | | NUMBER |
| 101 | | ONE |
| 102 | | FAR |
| 103 | | FROM |
| 104 | | CLOSE |
| 105X | FINAL CONTROL | |
| 106 | | IS |
| 107 | | ONE |
| 108 | | POINT |
| 109X | REMARKS | |
| 110X | INITIAL POINT | |
| 111 | | ZERO |
| 112 | | METERS |
| 113 | | GOING |
| 114 | | NORTH |
| 115X | HEADING | |
| 116 | | EAST |
| 117X | ELEVATION | |
| 118 | | SEVEN |
| 119 | | FEET |
| 120X | DESCRIPTION | |
| 121 | | VEHICLE |
| 122X | MARK | |
| 123 | | CODE |
| 124 | | ONE |
| 125 | | BLACK |
| 126 | | SMOKE |
| 127X | TIME ON TARGET | |
| 128 | | AFTERNOON |
| 129 | | AT |
| 130 | | TWO |
| 131X | HAZARDS | |
| 132 | | ZERO |
| 133 | | VISIBILITY |
| 134 | | BAD |
| 135 | | WEATHER |
| 136 | | HOT |
| 137 | | FEET |
| 138X | END REMARKS | |

END

FILMED

6-86

DTIC